HEALTH BEHAVIORS, AFFECT, AND ACADEMIC PERFORMANCE: THREE LONGITUDINAL STUDIES

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Declaration of Authorship

I, Lavinia Flückiger (born April 27, 1987), hereby declare the following:

(i) My cumulative dissertation is based on three manuscripts, of which one is published and two are submitted. I have contributed independently and substantially to this dissertation without any assistance from third parties not indicated.

(ii) I have used only the resources indicated.

(iii) I have cited all references.

Basel, April 8, 2015

Lavinia Flückiger

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Abbreviations

OECD	Organisation for Economic Co-operation and Development
WHO	World Health Organization

Deutsche Zusammenfassung

Ziel: Gesundheitsverhalten ist eine zentrale und zugleich stark schwankende Komponente des täglichen Lebens. Forschung zu dieser natürlichen Dynamik gibt es wenig. Die vorliegende Dissertation untersucht daher, wie Gesundheitsverhalten mit wichtigen Alltagsbereichen im jungen Erwachsenenalter zusammenhängen und verbindet dabei drei Forschungsrichtungen, indem sie Gesundheitsverhalten, Affekt, Stress und akademische Leistung in drei längsschnittlichen Beobachtungsstudien gemeinsam beleuchtet. ***Methode:*** Diese drei unabhängigen Längsschnittstudien wurden jeweils während des ersten Studienjahres über einen Zeitraum von bis zu acht Monaten durchgeführt (mit bis zu 65 Befragungstagen). Studierende berichteten ihre Schlafqualität, körperliche Aktivität, Snacking, positiven und negativen Affekt, erlebten Stress, und Lernzielerreichung (Studie A: $N = 72$, Studie B: $N = 292$, Studie C: $N = 304$). Die Daten wurden mittels Multilevel Mediations- und Moderationsanalysen ausgewertet. ***Resultate:*** Tage mit besserer Schlafqualität oder erhöhter körperlicher Aktivität als üblich, jedoch nicht Snacking, waren via erhöhtem positiven Affekt und verringertem negativen Affekt mit besserer Lernzielerreichung assoziiert. An stressreicheren Tagen als üblich stellten diese beiden Gesundheitsverhalten einen protektiven Faktor gegen die negativen Auswirkungen von Stress auf Affekt dar. Beinahe alle Resultate konnten über die drei Studien repliziert werden. ***Schlussfolgerungen:*** Einzelne Nächte mit besserer Schlafqualität oder einzelne Tage mit erhöhter körperlicher Aktivität als üblich, gerade an stressreichen Tagen, scheinen eine wertvolle Ressource für wichtige Alltagsbereiche im jungen Erwachsenenalter zu sein. Diese Befunde haben wichtige Implikationen für die Gesundheitsförderung und Stressprävention, mit dem Ziel junge Erwachsene in ihrem täglichen Leben zu unterstützen.

Abstract

Objective: Health behaviors are a fundamental and highly fluctuating component of everyday life. Evidence capturing these natural daily fluctuations is limited. Therefore, this dissertation investigates how these daily dynamics in health behaviors are associated with other important aspects of young adults' everyday lives and bridges separate research strands by integrating health behaviors, affect, stress, and academic performance in three intensive longitudinal studies. ***Method:*** These three longitudinal studies were conducted independently during three consecutive freshman years covering a period of up to eight months (with up to 65 assessment days). University students reported their sleep quality, physical activity, snacking, positive and negative affect, experienced stress, and learning goal achievement (Study A: $N = 72$, Study B: $N = 292$, Study C: $N = 304$). Data were analyzed using multilevel mediation and moderation analyses. ***Results:*** Days with better sleep quality or more physical activity than usual, but not snacking, were associated with better learning goal achievement through increased positive affect and decreased negative affect on those days. Especially on more stressful days than usual, these two health behaviors emerged as potential stress-buffers against the adverse effects of daily stress on affect. Importantly, the majority of the findings were replicated across the three studies. ***Conclusions:*** Single nights of better sleep quality or single days of more physical activity than usual, especially on stressful days are a valuable resource for young adults' daily functioning. These findings have the potential to inform health promotion and stress prevention programs aimed at supporting young adults in their everyday lives.

Introduction

> „Health is [...] seen as a resource of everyday life, and not the objective of living.“ (Ottawa Charter, World Health Organization [WHO], 1986).

Central elements of every person's overall health are physical, mental, and social health (WHO, 1946). The way of maintining physical health has markedly changed over the last decades since medicine and sanitation have impressively progressed and industrialization and urbanization have increased (Omran, 1971; Santosa, Wall, Fottrell, Hogberg, & Byass, 2014). This becomes clear as infectious diseases represented the leading causes of death 100 years ago (Centers for Disease Control and Prevention, 2015) which can be largely prevented or successfully treated these days (WHO, 2002). In contrast, chronic diseases have become the major causes of death nowadays (Hoyert & Xu, 2012). A main root of this rise in chronic diseases is a dramatic shift in living patterns toward less healthy behavior such as increasing physical inactivity and rising consumption of processed or „fast“ food (WHO, 2002). For example, physical inactivity increased between 2005 and 2012 from 17% to 31% worldwide (Hallal et al., 2012; WHO, 2009); similar results were estimated for Switzerland with 28% in 2012 (Bundesamt für Statistik, 2014). As a result, health behaviors such as physical inactivity and unbalanced eating have been identified as some of the major modifiable health-risk factors for chronic diseases in developed countries (WHO, 2015a; 2015b). An additional health behavior that has not markedly changed over the last decades (Bin, Marshall, & Glozier, 2012), but nevertheless is fundamental for physical health is sleep (Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011; Cappuccio, D'Elia, Strazzullo, & Miller, 2010). Hence, health behaviors such as sleep, physical activity, and eating play nowadays a crucial role in physical health (e.g., Cappuccio et al., 2010; Flegal, Kit, Orpana, & Graubard, 2013; Nocon et al., 2008).

However, according to the WHO not only physical health but also mental and social health are central for our overall health (WHO, 1946). But are health behaviors also beneficial for mental and social life domains and if yes, what are the specific benefits?

A growing line of research rooted mainly in the field of health and clinical psychology has shown that health behaviors such as physical activity, eating, and sleep are associated with improved mental health (Strohle et al., 2007; Walsh, 2011), including improved affect (Kahn, Sheppes, & Sadeh, 2013; Kanning, Ebner-Priemer, & Schlicht, 2013; Polivy & Herman, 2005) and better stress coping (Gerber & Puhse, 2009). Another line of research mainly situated in the fields of cognitive and educational psychology has suggested that health behaviors are linked with facets of social health such as better cognitive (Gomez-Pinilla, 2008; Lucke & Partridge, 2013) and academic performance (Burkhalter & Hillman, 2011; Busch et al., 2014), which are critical for tertiary graduation and income (Organisation for Economic Co-operation and Development [OECD], 2014) and thus may play a role in socioeconomic status in later life.

However, the combination of these two research lines has received little attention in the literature and thus less is known about how health behaviors, affect, stress, and academic performance are intertwined. Therefore, the present dissertation aims at bridging the separate research strands by investigating these concepts simultaneously. Furthermore, existing evidence of both lines of research have provided mainly a snapshot of a person's health behaviors and focused on the distinction between individuals, such as whether physically active individuals have better grades compared to physically inactive individuals (e.g., Hillman, Erickson, & Kramer, 2008). This approach portrays health behaviors as static rather than dynamic, characterizing them as a stable and persisting pattern. However, health behaviors undergo fluctuations across time and can change from one day to another (e.g., Kanning et al., 2013). Additionally, everyday life is full of affective swings, daily experiences of stressful and joyful events as well as achievements and failures that substantially contribute

to an individual's so-called good days or bad days. To catch such daily variations in behaviors and experiences in the changing context of everyday life, intensive longitudinal studies are needed (Bolger & Laurenceau, 2013).

Therefore, the objective of the present dissertation is to combine theses separate research strands in an intensive longitudinal study design to better understand how daily dynamics of three central health behaviors, namely, sleep quality, physical activity, and snacking are associated with affect and academic performance, two important aspects of daily functioning in young adults. Additionally, the potential protective role of health behaviors for affect on stressful days is examined. These issues are addressed in three papers. Two papers focused on the association between health behaviors and daily functioning: The first paper is an analysis of the association between two day-to-day health behaviors, namely, sleep quality and physical activity with affect and academic performance during a stressful four-week examination period. The second paper builds on the first paper by extending several aspects such as the observation period to an entire academic year, an additional health behavior (snacking), and two independent study samples allowing replication. The third paper reports on tests of the potential stress-buffering effect of health behaviors on affect in daily life. Three observational intensive longitudinal studies provided data for the three papers.

Taken together, this dissertation may have important implications for health promotion since prevention and intervention programs target mainly at changes within the same person, which is the focus of the present dissertation: Providing insights into how fluctuations in health behaviors, affect, and academic performance unfold within one person in the changing context of everyday life.

This dissertation is organized as follows: First, in the *Theoretical Background* I present the central theoretical and empirical work that motivated the present dissertation, point out the research gaps and introduce my research questions. This is followed by an overview of the *Methods* used in this research. In the *Results* section, I summarize the

findings of the three papers. Finally, in the *Discussion* I present my main conclusions and implications of the findings, giving an overview of the studies' strengths and limitations and providing perspectives for future research.

Theoretical Background

Health Behaviors

Health behaviors are described as behaviors that may affect an individual's health status (Ogden, 2010). These are distinguished between health-impairing behaviors that may have negative effects on health or may predispose individuals for disease (such as physical inactivity, unbalanced eating, non-restorative sleep, smoking, excessive alcohol or drug consumption) and health-enhancing behaviors that may have beneficial or protective effects on health (such as vaccination, sufficient physical activity, balanced eating, restorative sleep, or tooth brushing).

Health behaviors are usually established during the transition from adolescence to adulthood and may set patterns for later life (Borodulin et al., 2012; Ferreira, Twisk, Mechelen, Kemper, & Stehouwer, 2005). However, during this critical period many young adults tend to veer away from health-enhancing behaviors (Kwan, Cairney, Faulkner, & Pullenayegum, 2012). University students have been shown to change sleep patterns (Galambos, Vargas Lascano, Howard, & Maggs, 2013), decrease physical activity and daily consumption of fruit and vegetable over several university years (Small, Bailey-Davis, Morgan, & Maggs, 2013), and increase weight by 1.8 kg during the first year at university (Nikolaou, Hankey, & Lean, 2014; for a meta-analysis, see Vella-Zarb & Elgar, 2009). The first year at university may be a particularly pivotal period for establishing health behaviors since students undergo a transitional period in which they face social and academic challenges (Gall, Evans, & Bellerose, 2000). Therefore, university students and young adults in general are a particularly critical target group to investigate health behaviors and their potential

associations with daily functioning. For the purposes of this dissertation, the term health behaviors refers to an umbrella construct including sleep quality, physical activity, and snacking.

Sleep quality. Carskadon and Dement (2011) defined sleep as „a reversible behavioral state of perceptual disengagement from and unresponsiveness to the environment“ (p. 16). Sleep quality is described as subjective indices of sleep such as tiredness and feeling rested upon awakening and throughout the day (Harvey, Stinson, Whitaker, Moskovitz, & Virk, 2008). About 50% to 76% of university students reported generally poor sleep quality (Lund, Reider, Whiting, & Prichard, 2010; Wald, Muennig, O'Connell, & Garber, 2014). Importantly, in healthy young adults sleeping in the range of the recommended sleep duration (7–9 hours per night, National Sleep Foundation, 2015), sleep quality has been shown to be more strongly associated with daily measures of health and well-being compared to sleep duration (Pilcher, Ginter, & Sadowsky, 1997).

Physical activity. Physical activity is defined as any movement produced by skeletal muscles that requires energy expenditure above resting level (Caspersen, Powell, & Christenson, 1985). Public health recommendations suggest that healthy adults between the ages of 18 and 65 years get at least 30 min of moderate-intensity aerobic physical activity on five days every week or at least 20 min of vigorous-intensity aerobic physical activity on three days every week to promote and maintain health. Moderate- and vigorous-intensity physical activity can also be combined to meet these recommendations (Haskell et al., 2007). Among university students 40% to 58% do not meet the recommendations for physical activity (Irwin, 2004; Keating, Guan, Pinero, & Bridges, 2005; Wald et al., 2014), which is even above the estimate of 29% for general-population young adults in Europe (Hallal et al., 2012).

Snacking. Snacking is commonly defined as eating occasions different from main meals (breakfast, lunch, dinner). Nowadays a significant amount of our daily total food intake

consists of snacking (Piernas & Popkin, 2010) accounting for approximately 20% of the daily caloric intake of young adults (Zizza, Siega-Riz, & Popkin, 2001). Thus, snacking is one of the most important descriptors of eating. Snacking has increased over the last decades (Zizza et al., 2001) and is assumed by some researchers to be linked to obesity (Forslund, Torgerson, Sjöström, & Lindroos, 2005). Prevalence of overweight including obesity in university students ranges from 20% to 37% (Morrell, Lofgren, Burke, & Reilly, 2012; Nikolaou et al., 2014); estimates for young adults in developed countries are comparable at 28% (Ng et al., 2014). However, snacking has been also associated with reduced risk of overweight (Keast, Nicklas, & O'Neil, 2010). Thus, it remains unclear whether snacking is truly associated with overweight and obesity.

To summarize, health-enhancing behaviors among young adults and specifically among university students are rather low. But what are the specific benefits of health behaviors for young adults, especially for their everyday lives that might attract them to pursuit health-enhancing behaviors?

Health Behaviors and Daily Functioning

The term daily functioning is used to refer to an overall construct covering affect and academic performance, both crucial aspects of young adults' everyday lives.

Health behaviors and affect. Since nearly every person pursuits positive affect, affect[1] is a promiment element in everyday life (Lyubomirsky, Sheldon, & Schkade, 2005). One line of research has investigated how health behaviors are associated with affect. Better sleep quality has been associated with increased positive affect in cross-sectional (e.g., Bower, Bylsma, Morris, & Rottenberg, 2010; Lund et al., 2010) and a few longitudinal

[1] The terms *affect*, *emotion*, and *mood* are not consistently applied in the literature. Watson (2000) described emotions as extremely brief and highly intense feeling states, whereas mood refers to transient episodes lasting longer in duration. Affect is specified as relatively mild and low intensity feeling states and are more frequent in everyday life compared to emotions. As the focus in this dissertation is on daily variations, affect will be used to refer to an overall construct including positive and negative affect as specific components of affect (Watson, Clark, & Tellegen, 1988).

studies (Galambos et al., 2013; Sonnentag, Binnewies, & Mojza, 2008). Increased physical activity has been consistently linked to increased positive and decreased negative affect in cross-sectional (Reed & Buck, 2009), experimental (Hogan, Mata, & Carstensen, 2013; for a meta-analysis, see Reed & Ones, 2006), and longitudinal settings covering periods of one day to six weeks (for an overview, see Kanning et al., 2013). Regarding the role of snacking in affect, evidence remains unclear. Some research has shown that snacking was associated with pleasurable emotions (Desmet & Schifferstein, 2008) and increased positive affect in experimental studies (Benton, Slater, & Donohoe, 2001), whereas other evidence has established reduced positive affect (Hormes & Rozin, 2011) and guilt after snacking (Steenhuis, 2009).

Health behaviors and academic performance. Another line of research has examined how health behaviors are associated with academic performance. Notably, 60% of young adults enter university-level education across OECD countries; in Switzerland the proportion is 40% (OECD, 2012). Therefore, tertiary education accounts for a specific but substantial proportion of young adults. Academic performance in tertiary education is measured mainly by grades (Richardson, Abraham, & Bond, 2012). Grades are a common key requirement for continuation of studies and graduation, and thus for later income (OECD, 2014). However, about 30% of students entering tertiary education level leave university without a degree (OECD, 2013). Therefore, identifying behaviors that help young adults to better achieve their academic goals is of considerable importance.

Higher sleep quality has been linked to better academic performance (for a review, see Curcio, Ferrara, & De Gennaro, 2006; Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010), which is underlined by the vital role of sleep in memory consolidation (Rasch & Born, 2013). Likewise, in cross-sectional and experimental studies, higher levels and single bouts of physical activity have consistently been associated with better grades and better cognitive performance, respectively (for a meta-analysis, see Chang, Labban, Gapin, & Etnier, 2012;

for a review, see Hillman et al., 2008). A review of longitudinal studies of adolescents provided similar results (Busch et al., 2014). Increased snacking has been associated with better cognitive performance compared to less snacking (Miller, Benelam, Stanner, & Buttriss, 2013).

Potential mechanisms underlying the association between health behaviors and cognitive performance have been investigated mainly from a physiological perspective (for an overview concerning eating, see Gomez-Pinilla, 2008; physical activity, see Marmeleira, 2013; sleep, see Rasch & Born, 2013). For example, it has been suggested that physical activity may increase cortical volume and cerebral blood flow (Marmeleira, 2013). Potential psychological mechanisms have not been the focus of research to date. One potential mechanism might be affect: That is, health behaviors might be associated with academic performance via changes in affect.

Affect as an underlying candidate mechanism. Positive affect has been associated with academic performance (Lyubomirsky, King, & Diener, 2005). To date, one longitudinal study based on three assessment points over 1.5 year in university students showed that sleep quality was linked to better academic performance through reduced depressive symptoms (Wong et al., 2013). However, not only is enduring affect critical for academic performance, but also daily affect has been suggested to be involved in aspects of academic performance such as daily learning performance. Positive affect emerged as a predictor of improved task performance (Miner & Glomb, 2010) and higher learning goals the next day, whereas negative affect predicted lower learning goals (Richard & Diefendorff, 2011). Current affect has been proposed to serve as an informal source of information for evaluating situations. Especially in periods when immediate feedback is absent, such as when preparing for a major exam over several weeks, current affect may be used to evaluate achievement or to set learning goals (Richard & Diefendorff, 2011). According to the mood-as-information theory, affect reflects a monitoring system of progress and discrepancy in regard to goal achievement

(Schwarz & Clore, 2003). That is, positive affect indicates goal achievement, whereas negative affect signals that things are not going as they ought to. Hence, current affect may play an important role in everyday aspects of academic performance (Miner & Glomb, 2010; Richard & Diefendorff, 2011), which in turn has been linked to long-term achievement such as grades (Morisano, Hirsh, Peterson, Pihl, & Shore, 2010).

To sum up, one strand of research has shown that health behaviors are linked to better academic performance, another strand has proposed that day-to-day health behaviors are associated with improved affect, and yet another strand has suggested that improved daily affect is associated with better academic performance. Therefore, daily affect might be a promising psychological candidate mechanism[2] underlying the association between health behaviors and academic performance in everyday life.

However, modern everyday life is full of minor stressors or daily hassles that are not – unlike health behaviors – under a person's direct control. Such daily stressors have been proposed as one of the driving forces of daily fluctuations in an individual's affect and mostly linked to increased negative affect (e.g., Jacobs et al., 2007). Therefore, it is fundamental to identify daily behaviors that may help young adults to attenuate the adverse effects of daily stress on affect. Since affect is thought to be involved in various important life domains (Lyubomirsky et al., 2005), the potential impact of stress on affect is elucidated in more detail in the following.

Health Behaviors, Stress, and Affect

Daily stressors, in contrast to major life events, are described as minor hassles of day-to-day living such as work deadlines, traffic, or tensions with a significant other. Most of

[2] The term *mechanism* may imply causality. However, in this dissertation mechanism is used as a statistical term – that is, affect may explain variance of academic performance additionally to health behaviors. The study designs used in this dissertation do not allow to draw causal conclusions. Nevertheless, I use the term mechanism due to previous experimental and longitudinal research suggesting the above-reviewed directed associations between health behaviors, affect, and academic performance.

these daily stressors are not experienced as devastating, but their accumulation over time can trigger a stress reaction that is, notably, sometimes even stronger than reactions triggered by major life events (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Thoits, 2010). Stress is experienced when a person appraises a situation as psychologically or physiologically demanding that tax or exceed his or her ability to manage it (Lazarus & Folkman, 1984). Daily stressful events have been linked to reduced psychological well-being (Almeida, 2005), increased daily negative affect, and decreased positive affect (e.g., Jacobs et al., 2007).

But not only affect may vary during stressful times, but also health behaviors may change such as reduced physical activity (Steptoe, Wardle, Pollard, Canaan, & Davies, 1996), increased eating (Adam & Epel, 2007, although around 30% decrease eating), and altered sleep (Galambos et al., 2013). In contrast, however, evidence has suggested that physical activity may buffer the adverse effects of stress. Various experimental and cross-sectional studies have established that the association between increased stress and decreased depressive symptoms was weaker in more physically active compared to less physically active individuals (Childs & de Wit, 2014; Ensel & Lin, 2004; Mata, Hogan, Joormann, Waugh, & Gotlib, 2013; Norris, Carroll, & Cochrane, 1992; Rejeski, Thompson, Brubaker, & Miller, 1992). One longitudinal study based on two assessment points ten months apart underlines the potential protective effect of physical activity (Klaperski, Seelig, & Fuchs, 2012).

In sum, previous research has mainly investigated the potential stress-buffering role of physical activity from a between-person or static perspective. However, considering the fluctuations in daily stress, it is essential to better understand the dynamic associations between stress, physical activity, and affect in everyday life. Additionally, it is unknown whether health behaviors such as sleep quality and snacking have similar potential stress-buffering effects to those of physical activity. As reviewed above, sleep quality has been associated with increased positive affect, indicating a potential protective effect during

stressful times. In contrast, concerning snacking, some evidence has suggested increased positive affect and other evidence has pointed to increased negative affect after snacking. Therefore, it is unclear whether snacking has a stress-buffering or a deteriorating effect on affect.

Research Gap and Research Questions

Taken together, three research strands inspired this dissertation. The first, situated in the field of health and clinical psychology, has indicated that health behaviors are linked to affect, and that health behaviors might have stress-buffering effects against deteriorated affect. The second research line, mainly rooted in educational, cognitive, and physiological psychology, has addressed the involvement of health behaviors in academic performance. The third research strand, stemming mainly from positive and social psychology, has suggested that affect may play an important role in academic performance. However, until now, integrating these three strands – health behaviors, affect, and academic performance – has received little attention in the literature. The combination of these research strands offers the possibility to better understand how they are intertwined and to elucidate potential mechanisms underlying the association between health behaviors and academic performance.

Furthermore, the vast majority of existing research is of an experimental or cross-sectional nature. Findings established in experimental settings may be decontextualized and thus not transferable to the real world; findings established in cross-sectional studies represent a person's behavior or experience as a snapshot based on a single assessment point. Existing longitudinal studies are either of short duration or have long assessment intervals and thus cannot capture naturally occurring fluctuations in everyday life. To gain insight into how day-to-day health behaviors and daily functioning unfold within the same person, intensive longitudinal studies are needed (Bolger & Laurenceau, 2013). As intervention and prevention programs focus on changes within an individual, this approach may enhance our

understanding to improve daily functioning in young adults in good mental and physical health.

Therefore, the objective of this dissertation is to use an intensive longitudinal study design in order to obtain a sensitive and dynamic perspective on health behaviors, affect, and academic performance in the changing context of everyday life such as daily stress. Specifically, two research questions are examined (see Figure 1):

1. How are day-to-day health behaviors associated with young adults' daily functioning including affect and academic performance in everyday life?
2. What are the potential benefits of health behaviors for affect on stressful days?

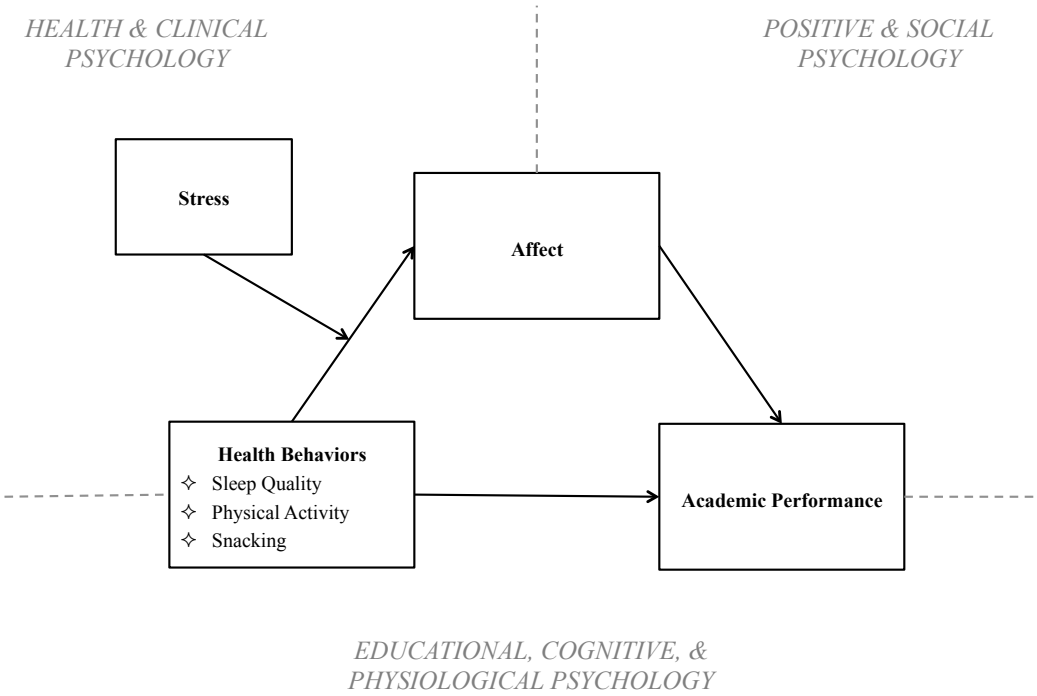

Figure 1: Overview of associations examined in this dissertation combining different research fields. Importantly, Research Question 1 (health behaviors, affect, and academic performance) was separately tested from Research Question 2 (health behaviors, stress, and affect). They are included in the same figure only for illustration and summary purposes.

The first research question was addressed in two papers:

Paper 1: How health behaviors relate to academic performance via affect: An intensive longitudinal study (published in *PLOS ONE*)

- Are day-to-day sleep quality and physical activity associated with affect and academic performance over a stressful examination period?
- Is daily affect a mechanism underlying the association of day-to-day sleep quality and physical activity with academic performance?

Paper 2: Day-to-day variations in health behaviors and daily functioning: Two intensive longitudinal studies (under review in *Health Psychology*)

- Can the day-to-day associations reported in Paper 1 be extended to two longitudinal studies covering an entire academic year and to an additional health behavior, namely, snacking?
- Is one health behavior more relevant for daily functioning compared to the others?

The second research question was addressed in the third paper:

Paper 3: The importance of physical activity and sleep for affect on stressful days: Two intensive longitudinal studies (submitted to *Emotion*)

- Can we observe changes in the associations between day-to-day sleep quality, physical activity, and snacking with affect with respect to daily stress?

Method

Intensive Longitudinal Study Design

The three studies that are the foundation of this dissertation were based on an observational intensive longitudinal study design. Such designs make it possible to study a person's behaviors and experiences as they occur in everyday life and hence to gain better ecological validity compared to single assessments or experimental settings (Walls & Schafer, 2006). Additionally, this study design may reduce recall bias as it allows researchers to

capture aspects of daily life that are difficult to recall, such as time of physical activity during the previous day (Shiffman, Stone, & Hufford, 2008). Furthermore, this approach allows intraindividual comparison, that is the comparison of each person with herself over time. Therefore, interindividual differences such as sex, social status, and age are eliminated as every person serves as his or her own control (Bolger, Davis, & Rafaeli, 2003).

Figure 2 gives an overview of the three studies (Study A, Study B, and Study C) used in this dissertation. The three intensive longitudinal studies were conducted in three independent study samples during three consecutive freshman years at the University of Basel, Switzerland covering a period of up to eight months.

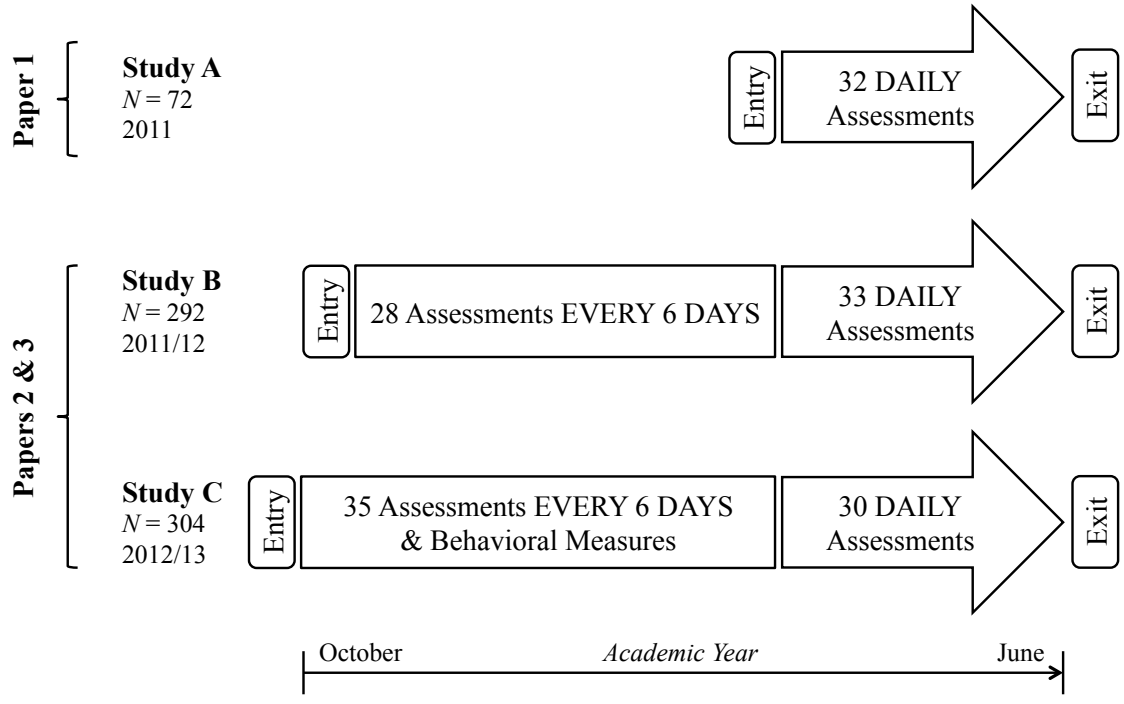

Figure 2: Overview of the general study designs of the three studies used in this dissertation. Every study included an entry assessment, day-level assessments, and an exit assessment. Additionally in Study C, behavioral measures of health behaviors were obtained in order to complement self-report data on health behaviors assessed in the day-level online assessments.

Importantly, Studies B and C extended Study A in several important ways: The observation period was expanded from a four-week examination period based on 32 daily assessments to an entire academic year, namely eight months with a higher number of assessment days (Study B: 61 assessment days; Study C: 65 assessment days), larger study samples, and more diverse study majors (e.g., psychology, economics, law, natural sciences). Further, an additional health behavior was considered, namely, snacking. In addition, to complement self-report data on health behaviors, behavioral measures were obtained in Study C such as snack intake in a laboratory setting and sleep and physical activity measured by actigraph watches.

First-year university students are a particularly suitable sample for three reasons: First, they undergo similar stressful (examination periods) and nonstressful periods (vacation periods). Hence, they are in a natural but relatively controlled setting. Second, the majority of students are of comparable educational background and age. Therefore, the sample is relatively homogeneous. Third, as Internet access is provided by the university, online assessment is unlikely to induce a selection bias.

Measures

In all three studies, participants completed various online assessments: an entry assessment, five-min assessments every six days (only Studies B and C) as well as on a daily basis, and an exit assessment (see Figure 1 for details). The day-level assessments measured sleep quality, physical activity, snacking, positive and negative affect, stress intensity and learning goal achievement over the previous 24 hours. In all three studies the following measures were used: *Sleep quality* was evaluated with the item of the established Pittsburgh Sleep Quality Index showing the highest single item–total correlation (Riemann & Backhaus, 1996). *Physical activity* was measured with an adapted version of the Godin Leisure-Time Exercise Questionnaire exhibiting adequate concurrent validity (Godin & Shephard, 1985; for adapted version, see Mata et al., 2012). In Studies B and C, *snacking* was calculated by the

sum of high-fat sweet snacks, high-fat savory snacks, low-fat savory snacks, and other snacks; fruit and vegetable snacks were not included. In Studies B and C, *stress intensity* was obtained by asking participants whether they experienced stressful events and if yes, how stressful they were (c.f., O'Connor, Jones, Conner, McMillan, & Ferguson). In all three studies, *positive and negative affect* were assessed with the Pleasantness Scale (Roecke, 2006). This scale yielded comparable results to the Positive and Negative Affect Schedule, which has shown high validity and reliability, and appears to be sensitive to short-term fluctuations in young adults (Watson et al., 1988). As a measure of daily academic performance, *learning goal achievement* was obtained by asking participants whether they had achieved their self-set learning goals (see Richard & Diefendorff, 2011). To determine external validity of daily learning goal achievement, average end-of-year examinations which participants reported in the exit assessment, were associated with average learning goal achievement over the entire observation period.

In Studies B and C participants were additionally invited to a laboratory session. In order to validate self-reported snacking, snack intake was behaviorally measured by offering participants a plate with four different snacks (n = 150) during a 10 min relaxation period at the end of the laboratory session in Study C. The remaining data of the laboratory session of Studies B and C were not integrated in the analyses since the present dissertation focuses on associations in everyday life. To complement self-report data on physical activity and sleep by behavioral measures, an additional subsample in Study C wore actigraph watches during seven consecutive days (n = 55). For details concerning the behavioral measures see Appendix B.

Statistical Analyses

For all analyses, multilevel regression analyses were applied, which are appropriate for the nested structure of repeated-measures data (Raudenbush & Bryk, 2002). To test the mechanism or intermediary process that leads from health behaviors (predictor) to learning

goal achievement (outcome) via affect (mediator) multilevel mediation analyses were conducted (MacKinnon, Fairchild, & Fritz, 2007). These were applied in Papers 1 and 2. To identify whether daily stress modifies the association between health behaviors and affect in terms of magnitude or direction, multilevel moderation analyses were conducted in Paper 3.

Results

Two important issues need to be clarified at the beginning of this section. The first issue concerns the structure of the results. Paper 1 is based on Study A (32 days during the stressful examination period). Studies B and C have very similar study designs (both over an entire academic year with 61 and 65 assessment days) and thus allow replication (see Figure 2). Papers 2 and 3 are therefore both based on Studies B and C for replication purposes. Importantly, Paper 1 (Study A) and Paper 2 (Studies B and C) both examine, first and foremost, how health behaviors are associated with affect and academic performance in everyday life. Hence for clarity and simplicity, the structure of the *Results* section follows the three studies and not the three papers.

The second issue concerns the between-person associations. In Paper 1 based on Study A between-person associations of health behaviors, affect, and academic performance were analyzed in addition to the intraindividual within-person associations, which can be different to the between-person associations (Molenaar, 2004). However, as the main focus of this dissertation is on day-to-day fluctuations that is within-person associations, between-person results are not reported here. For detailed information concerning the between-person results, see Appendix A. Although a between-person perspective is methodologically most similar to traditional well-documented cross-sectional research, it is important to note that the average of behavior and experience based on an intensive repeated day-level assessment rather than derived from a single assessment point may provide a more accurate picture of the between-person characteristics.

Day-to-Day Health Behaviors and Daily Functioning

Importantly in Study C, behaviorally measured snack intake, physical activity and sleep were associated with self-reported snacking, physical activity, and sleep, respectively, obtained in the online assessments. Figure 3 illustrates the within-person results of the two research questions based on all three studies: The mediation analyses based on the associations between day-to-day health behaviors and learning goal achievement via affect (sleep quality and physical activity: Studies A, B, and C; snacking only Studies B and C) and the moderation analysis based on daily stress as moderator in the association between health behaviors and affect (Studies B and C).

Daily affect. As can be seen in Figure 3, across all three studies, on days for which participants reported better sleep quality or more physical activity than usual, they also reported increased positive and decreased negative affect. This finding was established during a stressful examination period (Study A) as well as over an entire academic year (Studies B and C). Snacking was analyzed only in Studies B and C: More day-to-day snacking was associated only with increased positive affect in Study B and was not associated with negative affect in either study.

Daily academic performance. On days for which participants reported better sleep quality, they also reported better learning goal achievement across all three studies, whereas the association with increased day-to-day physical activity was established only in Study C. Day-to-day snacking was not associated with learning goal achievement in either Study B or C. Notably across the three studies, better learning goal achievement averaged over the observation period was associated with better average end-of-year examination grades.

Daily affect as underlying mechanism. Daily increased positive and decreased negative affect were associated with better learning goal achievement across all three studies. Concerning the mediation analyses results showed that daily positive and negative affect mediated the association between sleep quality and learning goal achievement across all three

studies. This means that better daily sleep quality was associated with better learning goal achievement through increased positive and decreased negative affect. Day-to-day physical activity was indirectly[3] associated with better learning goal achievement via increased positive and decreased negative affect across all three studies. In contrast, day-to-day snacking was only indirectly associated with learning goal achievement via increased positive affect in Study B, but not in Study C.

Importantly, day-to-day sleep quality emerged as the strongest predictor for positive and negative affect, and learning goal achievement compared to physical activity and snacking in Studies B and C (Snacking was not tested in Study A).

Health Behaviors and Affect on Stressful Days

In Studies B and C, better sleep quality was more strongly associated with increased positive (both studies) and decreased negative affect (only in Study C) the more stressful than usual a day was said to be. Likewise, higher physical activity was more strongly associated with increased positive (only in Study B) and decreased negative affect (both studies) the more stressful than usual a day was. The association between day-to-day snacking and positive and negative affect did not differ with respect to the daily stress level.

[3] The term *mediation* implies an initially present total effect, whereas an *indirect effect* can be detected without this assumption (Preacher & Hayes, 2004).

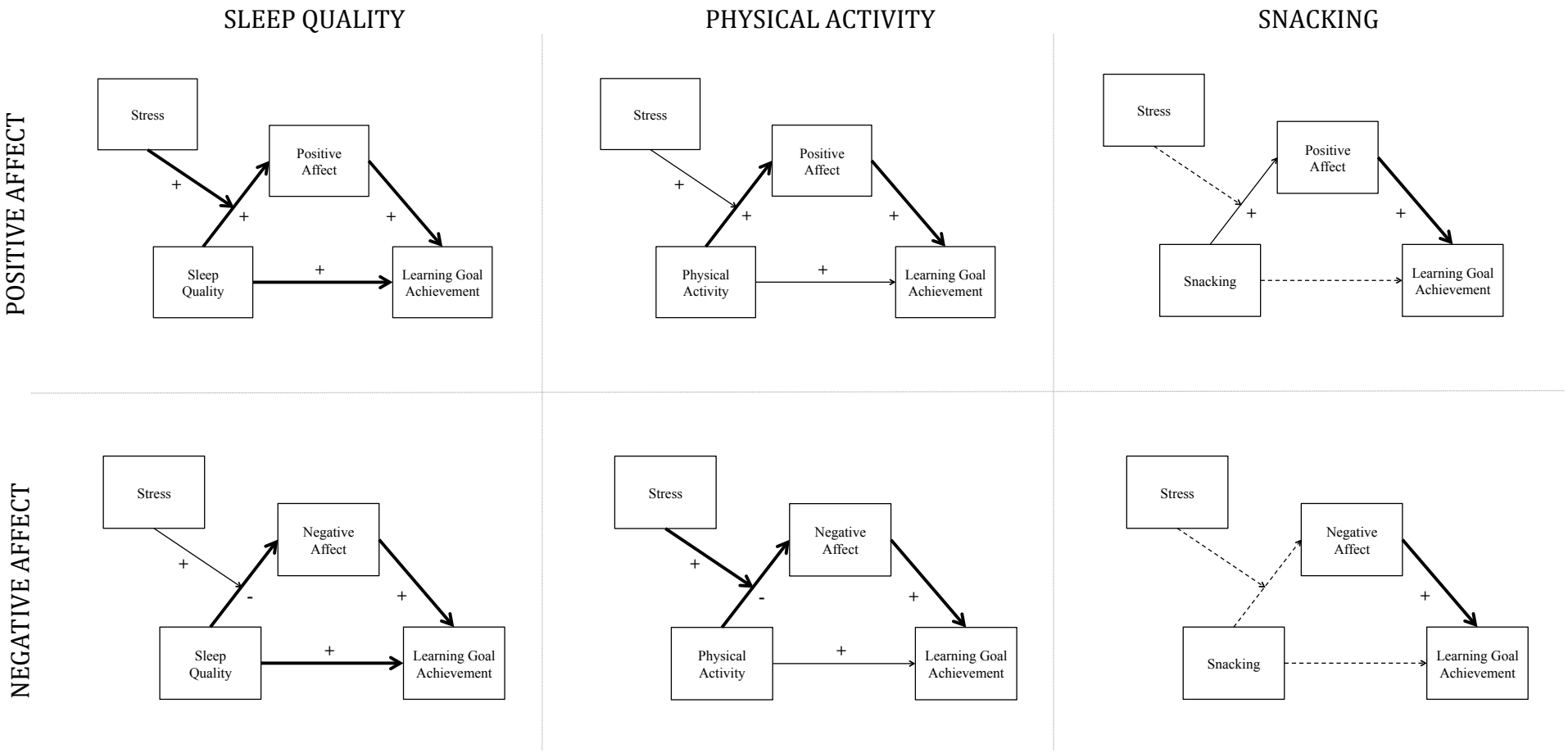

Figure 3: Summary of the day-to-day associations between health behaviors, affect and learning goal achievement. Note that the *moderation analyses* testing stress as moderator of the association between health behaviors and affect was analyzed separately from the *mediation analyses*; they are included in the same figure only for illustration and summary purposes. Importantly, the mediation analyses including sleep quality and physical activity as predictors were based on Studies A, B, and C. The remaining analyses, namely, the mediation analysis including snacking as predictor as well as the moderation analyses were only based on Studies B and C. Solid thick line: Association was replicated (either among two or three studies); solid slim line: Association was not replicated; dashed line: Lack of association replicated; positive sign: Positive association or in terms of daily stress, strengthening the association; negative sign: Negative association.

Discussion

The present dissertation extends existing evidence by investigating the potential benefits of specific health behaviors in young adults' daily functioning from a dynamic perspective. In order to gain better insight into how these daily variations in health behaviors, affect, stress, and academic performance unfold in the context of everyday life, three intensive longitudinal studies integrated three separate research strands by evaluating these concepts simultaneously. First, single nights of better sleep quality or single days of more physical activity than usual are associated with improved daily affect and better academic performance. Second, the results suggest that day-to-day physical activity and sleep quality may buffer the detrimental effects of daily stress on affect. No associations emerged for daily snacking. Importantly, the three studies yielded almost congruent results. Findings of this dissertation may be relevant for health promotion and stress prevention programs providing everyday strategies to support young adults in their daily functioning.

Day-to-Day Health Behaviors and Their Implications for Daily Functioning

The first research question addressed how day-to-day health behaviors were associated with affect and academic performance in young adults' everyday lives.

Daily affect. Results of the three studies indicate that patterns of day-to-day variations in affect differed regarding the three health behaviors. Days with better sleep quality or more physical activity than usual were consistently linked with increased positive and decreased negative affect converging with previous experimental (Mata et al., 2013; Reed & Ones, 2006) and longitudinal research (Bower et al., 2010; Kanning et al., 2013; Simor, Krietsch, Koteles, & McCrae, 2015; Sonnentag et al., 2008). Although there is growing longitudinal evidence, no study has elucidated the dynamics of health behaviors and affect over an eight-month period with this high number of assessment days (up to 65). This provides a clearer picture of how health behaviors and affect are intertwined in daily life and underscores the importance of sleep quality and physical activity for daily affect. Concerning the third health

behavior, day-to-day snacking was consistently not associated with negative affect; results for positive affect were mixed. Since these findings contradict previous results (Desmet & Schifferstein, 2008; Hormes & Rozin, 2011; Steenhuis, 2009), one explanation might be that the present study design based on one assessment per day might not have been able to capture the relatively short-lived associations (see Perspectives for Future Research).

Daily academic performance. Better day-to-day sleep quality was consistently associated with better academic performance whereas day-to-day snacking consistently was not. Results for day-to-day physical activity were mixed. Importantly, average daily academic performance predicted examination grades at the end of the first year, emphasizing the importance of short-term achievements for long-term outcomes.

The current results extend previous cross-sectional (Burkhalter & Hillman, 2011; Curcio et al., 2006; Dewald et al., 2010; Miller et al., 2013) and experimental research (Chang et al., 2012) by providing a process-oriented perspective on health behaviors and academic performance in everyday life. Existing evidence has shown that better sleep quality in general is associated with better academic performance, whereas the present results point out that even single nights of better sleep quality are linked to better academic performance on those days. These findings have compelling practical implications for low-threshold prevention and intervention programs aimed at helping young adults to better achieve their academic goals. For example, one relevant message for young adults might be that not only regular sleep, but even a single night of better sleep quality may support their academic performance.

Daily affect as underlying mechanism. Findings consistently showed that better sleep quality and increased physical activity were indirectly associated with better academic performance through increased positive and decreased negative affect. This was not consistently established for snacking. Testing daily affect as an underlying mechanism adds to the existing evidence: (1) This approach bridges three separate research strands rooted in health (e.g., Walsh, 2011), cognitive psychology (Lucke & Partridge, 2013), and positive

psychology (e.g., Richard & Diefendorff, 2011) by investigating three different health behaviors, affect, and academic performance. (2) Affect emerged as the link between two health behaviors and academic performance, offering new insights into intermediary processes in the context of everyday life and extending prior research on physiological mechanisms (Marmeleira, 2013) by a promising psychological mechanism. (3) The results emphasize the importance of fostering the understanding of underlying mechanisms. For example, although the results did not consistently establish an association between day-to-day physical activity and academic performance, physical activity is associated with better academic performance through improved daily affect.

Health behavior specificity. Findings consistently yielded that day-to-day sleep quality is more relevant for improved daily functioning compared to physical activity or snacking. At a first glance, this finding may appear to be relatively clear-cut since it is well known that sleep is a core element of everyday life. However, very few studies have compared the benefits of specific health behaviors for daily functioning. Although almost every person has experienced nights of good and poor sleep quality, one might not be aware of the strong link between sleep and other aspects of everyday life. The high prevalence of poor sleep quality among university students emphasize that sleep is of great concern (e.g., Lund et al., 2010). However, major targets of health promotion are e.g., balanced eating, sufficient physical activity, and smoking, whereas the promotion of good sleep has not been in the focus. Therefore, health promotion programs might aim at raising young adults' awareness of the strong link of sleep quality with affect and academic performance. This might be supplemented by practical strategies to improve their sleep quality, such as sleep hygiene recommendations (Mastin, Bryson, & Corwyn, 2006). Moreover, short sleep duration has been shown to play a critical role in physical activity and eating (Cappuccio et al., 2008; Garaulet et al., 2011). Therefore, promoting good sleep quality might not only be an approach to improve daily functioning but also to potentially facilitate other health behaviors.

Taken together, the present findings may contribute to a better understanding of how health behaviors are associated with affect and academic performance in young adults' everyday lives. This may provide a basis for health promotion including prevention and intervention programs aimed at supporting young adults to better achieve their academic goals in good physical and mental health. Especially, the finding that health behaviors may not only be beneficial for long-term physical health but also for short-term daily functioning, might be a strong message to encourage young adults to follow health-enhancing behaviors. For example, prevention and intervention programs could inform young adults about the benefits of good sleep quality and physical activity for their daily affect and academic performance by pointing out that not only regular patterns of sleep and physical activity are crucial, but even single nights of better sleep quality or single days of more physical activity than usual (i.e., „a bit" more than usual or „small" changes in one's usual health behavior, independent of, for example, how physically active a person is on average) may improve their daily functioning.

Such low-threshold approaches might provide a starting point to facilitate health behavior change toward health-enhancing behavior. This could extend existing health promotion programs which mainly target at enhancing regular sleep and physical activity patterns. Especially in the context of public health recommendations, which convey a rather rigid perspective on health behaviors, such as meeting recommendations or not, this „more-than-usual" characteristic might provide a more flexible approach. This might facilitate the awareness of short-term benefits of health behaviors and thus might be a motivational boost to start pursuing health-enhancing behaviors. Although the focus of such an approach would be on short-term health behavior change, this might be also a potential gateaway for long-term changes.

Health Behaviors on Stressful Days and Their Implications for Affect

The second research question aimed at investigating the potential stress-buffering role of day-to-day health behaviors on affect. On days with more stress than usual, sleep quality

and physical activity, but not snacking, appeared to offer protection against deteriorated affect. Especially in the context of modern life, which is full of minor stressors changing from one day to another, it is a valuable approach to look beyond stress as a rather stable pattern (Childs & de Wit, 2014; Klaperski et al., 2012; Mata et al., 2013) and take a process-oriented perspective on daily stress. This may enhance our understanding of health behaviors as potential resource to cope with stress in everyday life and thus might provide daily strategies for stress management, which might be implemented in prevention and intervention programs aimed at stress coping. These might, for example, inform young adults that good sleep quality or engaging in physical activity may help them to recover from daily stress. Importantly, beyond the well documented stress-buffering effect of physical activity, sleep quality but not snacking emerged as an additional potential protective factor against deteriorated affect.

Stress also plays a crucial role in memory consolidation and learning performance (Schwabe, Joels, Roozendaal, Wolf, & Oitzl, 2012). As the present results show that day-to-day sleep quality and physical activity are involved directly and indirectly via changes in affect with academic performance, it could be speculated that good sleep quality and physical activity might also serve as protection against lower academic performance on stressful days. As during examination periods neuroenhancing drugs has been shown to be used (Maier, Liechti, Herzig, & Schaub, 2013 for Switzerland), it is essential from a public health perspective to inform students about ethically more appropriate strategies (Lucke & Partridge, 2013) such as, good sleep quality and engaging in physical activity. However, as in this dissertation the potential stress-buffering effect of health behaviors on academic performance was not tested, future research should explore the potential benefits of health behaviors on academic performance with respect to daily stress.

Implications Beyond Young Adults

The present findings might have not only implications for young adults but also for a broader context and thus are discussed in a speculative manner. Academic performance is one

example of work- and cognitive-related performance and thus might be relevant to populations from adolescents to older age. In addition, affect is crucial across the entire lifespan (Roecke, Li, & Smith, 2009). Hence, two public health messages might be offered: First, the result that health behaviors are not only central for long-term physical health, but also crucial for other important aspects of everyday life such as affect and work-related performance may be of interest beyond young adults. Secondly, the low-threshold approach, namely, that single days with more physical activity or single nights with better sleep quality than usual may have benefits for daily functioning, might not only encourage young adults to set a starting point toward healthier behavior but also age groups across the entire lifespan. In addition, health behaviors as potential resource to recover from daily stress would be a healthy approach to combat stress. These messages might contribute to a better understanding of the relevance of health behaviors for important aspects of everyday life in the general population.

Such messages might be a basis to inform health promotion. Health promotion aims at facilitating biological, behavioral, social, environmental, political, and economic factors in order to favour health (WHO, 1986). The present results might provide information concerning the individual behaviors for health promotion targeting at health education and developing personal skills, key components of health promotion on the behavioral level (WHO, 1986). Although the behavioral factor is only one among many factors, it may be a valuable approach: Individuals are able to directly control their health behaviors in contrast to environmental factors. Moreover, single individuals are the foundation of society, which in turn is linked to political and economic factors. For example from an economic perspective, physical inactivity represents a substantial economic burden for the society, e.g., the related direct healthcare costs were estimated at CHF 1.165 bilion or 1.8% of the total health care costs were due to physical inactivity in Switzerland in 2011 (Mattli et al., 2014); even higher health care costs were estimated in other developed countries such as USA, Canada and

United Kingdom (Oldridge, 2008). This additionally underlines the importance of effective health promotion programs targeted at health-enhancing behaviors in individuals, which are the basis of social, economic, and political issues.

Strengths and Limitations

Several strengths can be acknowledged: (1) One of the most valuable strengths of the present dissertation is the very *intensive longitudinal study design*. The three studies covered up to 65 assessment days over a period of up to eight months, providing a picture of daily dynamics in health behaviors and daily functioning that appear rather static in cross-sectional and experimental designs. Each individual was compared with his or her own average, which allowed a process-oriented perspective within the same individual. Such findings may be directly implemented in prevention and intervention programs which focus mainly on changes within individuals. Additionally, the observational nature of the present study design reflecting an individual's natural environment, may allow to generalize the present results to real-world experiences (Shiffman et al., 2008). (2) A day-level approach *minimized recall biases* that are more likely in traditional retrospective self-report assessments (Almeida, 2005; Bolger et al., 2003). (3) *Different measurement approaches* were combined including repeated online assessments, a laboratory session, and a 1-week actigraph study. The two latter approaches were intended to behaviorally measure snack intake (laboratory session), sleep, and physical activity (actigraph watches) in order to validate self-reported health behaviors obtained in the online assessments. (4) *Multiple health behaviors* were simultaneously examined to explore their specific associations with daily functioning. Since health behaviors have been mainly investigated separately, the present dissertation grants insight into health-behavior specificity for daily functioning. (5) The similarity of the three studies enabled *replication.* With the exception of four results, all findings were replicated.

The following limitations should be considered: (1) The present study design did not allow drawing any conclusions about *directionality and causality*. Even though the theoretical models used in the present dissertation imply a causal direction from health behavior to better academic performance via improved affect, the current results can be interpreted only in associative rather than in causal terms. (2) All data were collected by *self-report* ratings which are suspect of recall bias. For example, food intake has been shown to be mostly underreported (Stubbs et al., 2014). However, self-reported snacking, sleep, and physical activity were associated with behaviorally measured snack intake, sleep, and physical activity, respectively, indicating that self-report was taken to be an adequate measure for health behaviors in this dissertation. (3) Although replication is a major strength of this dissertation, four results were contradictory. Therefore, future research is needed to clarify these discrepancies (see Perspectives for Future research). (4) Since results cannot be transferred to other universities and ages, *generalization* of the present findings is limited.

Perspectives for Future Research

From a *micro-level perspective*, future studies should investigate the associations between day-to-day health behaviors, stress, and daily functioning in a more intense study design such as multiple assessments per day. Although assessments on a day-level basis were accurate regarding the time period of up to eight months in order to keep participants burden acceptable, assessments with higher frequency might be a valuable approach to gain temporal information on proximal states and contexts (Walls & Schafer, 2006). Especially, the relatively constant lack of association between snacking and daily functioning might be due to this aspect of study design, namely, that one assessment point per day might not have captured the potential short-lived associations. This should be elucidated in future studies. Furthermore, the additional contradictory results among the three studies need further clarification: The association between physical activity and academic performance; the stress-buffering role of sleep quality for negative affect, and the stress-buffering role of physical

activity for positive affect. Additional health behaviors such as tobacco and alcohol consumption should be considered as well.

From a *macro-level perspective*, epidemiological studies would be a fruitful approach to gather more information of the associations between health behaviors, affect, and work performance on a population level rather than limited to a specific target group, namely, university students in order to allow conclusions about a broader population.

From a *health promotion perspective,* it would be beneficial to extend health promotion programs focusing mainly on balanced eating and physical activity by the link between sleep and daily functioning, and to evaluate whether this is of young adults' interest as well as whether it has the potential to raise their awareness. Furthermore, the low-threshold approach could be implemented in intervention programs aimed at health behavior change in order to test whether such an approach might be encouraging to start health behavior change as well as to maintain health-enhancing behaviors. Especially, the years at university are an ideal period to provide support and information regarding health behaviors and their relevance.

In addition, it would be valuable to better understand how various health behaviors interact in order to optimize health behavior promotion and change. Some studies yielded an interplay between different health behaviors suggesting either synergistic (Garaulet et al., 2011; Mata et al., 2009; Schubert, Desbrow, Sabapathy, & Leveritt, 2013) or compensatory associations (King et al., 2013; Wilcox, King, Castro, & Bortz, 2000). Therefore, future research should examine whether health behaviors such as sleep, physical activity, eating, smoking, and alcohol consumption show synergistic or compensatory effects on daily functioning in order to provide a more concise picture of the interplay of health behaviors for health promotion programs.

Conclusions

Good sleep quality and physical activity may be a valuable resource for important aspects of daily functioning in young adults' everyday lives. Whereas snacking did not appear to be involved in young adults' daily functioning, single nights of better sleep quality and single days of more physical activity than usual are consistently associated with improved affect and academic performance – even more on stressful days. This contributes to a better understanding of how young adults' may improve their daily functioning in good physical and mental health.

Although results of this dissertation are a starting point for a better understanding of how daily dynamics in health behaviors are associated with affect and academic performance, the findings are promising and suggest that health behaviors and aspects of mental and social health are intertwined in everyday life. This has the potential to inform health promotion aimed at good health – a resource of everyday life and thus a central resource for personal, social, and economic development.

References

Adam, T. C., & Epel, E. S. (2007). Stress, eating and the reward system. *Physiology and Behavior, 91*, 449–458. doi: 10.1016/J.Physbeh.2007.04.011

Almeida, D. M. (2005). Resilience and vulnerability to daily stressors assessed via diary methods. *Current Directions in Psychological Science, 14*, 64–68. doi: 10.1111/J.0963-7214.2005.00336.X

Benton, D., Slater, O., & Donohoe, R. T. (2001). The influence of breakfast and a snack on psychological functioning. *Physiology and Behavior, 74*, 559–571. doi: 10.1016/S0031-9384(01)00601-1

Bin, Y. S., Marshall, N. S., & Glozier, N. (2012). Secular trends in adult sleep duration: A systematic review. *Sleep Medicine Reviews, 16*, 223–230. doi: 10.1016/j.smrv.2011.07.003

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology, 54*, 579–616. doi: 10.1146/Annurev.Psych.54.101601.145030

Bolger, N., & Laurenceau, J.-P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research*. New York, NY: The Guilford Press.

Borodulin, K., Makinen, T. E., Leino-Arjas, P., Tammelin, T. H., Heliovaara, M., Martelin, T., . . . Prattala, R. (2012). Leisure time physical activity in a 22-year follow-up among Finnish adults. *International Journal of Behavioral Nutrition and Physical Activity, 9*, 121. doi: 10.1186/1479-5868-9-121

Bower, B., Bylsma, L. M., Morris, B. H., & Rottenberg, J. (2010). Poor reported sleep quality predicts low positive affect in daily life among healthy and mood-disordered persons. *Journal of Sleep Research, 19*, 323–332. doi: 10.1111/J.1365-2869.2009.00816.X

Bundesamt für Statistik. (2014). Gesundheitsstatistik 2014 [Health statistics 2014]. Retrieved from

http://www.bfs.admin.ch/bfs/portal/de/index/dienstleistungen/publikationen_statistik/publikationskatalog.html?publicationID=5765

Burkhalter, T. M., & Hillman, C. H. (2011). A narrative review of physical activity, nutrition, and obesity to cognition and scholastic performance across the human lifespan. *Advances in Nutrition, 2*, 201–206. doi: 10.3945/An.111.000331

Busch, V., Loyen, A., Lodder, M., Schrijvers, A. J. P., Yperen, T. A. van, & de Leeuw, J. R. J. (2014). The effects of adolescent health-related behavior on academic performance: A systematic review of the longitudinal evidence. *Review of Educational Research, 84*, 245–274. doi: 10.3102/0034654313518441

Cappuccio, F. P., Cooper, D., D'Elia, L., Strazzullo, P., & Miller, M. A. (2011). Sleep duration predicts cardiovascular outcomes: A systematic review and meta-analysis of prospective studies. *European Heart Journal, 32*, 1484–1492. doi: 10.1093/Eurheartj/Ehr007

Cappuccio, F. P., D'Elia, L., Strazzullo, P., & Miller, M. A. (2010). Sleep duration and all-cause mortality: A systematic review and meta-analysis of prospective studies. *Sleep, 33* (5), 585–592.

Cappuccio, F. P., Taggart, F. M., Kandala, N. B., Currie, A., Peile, E., Stranges, S., & Miller, M. A. (2008). Meta-analysis of short sleep duration and obesity in children and adults. *Sleep, 31*(5), 619–626.

Carskadon, M. A., & Dement, W. C. (2011). Normal human sleep: An overview. In M. H. Kryger, T. Roth & W. C. Dement (Eds.), *Principles and practice of sleep medicine* (pp. 16–26). St. Louis, MO: Elsevier Saunders.

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports, 100*, 126–131.

Centers for Disease Control and Prevention. (2015). Leading causes of death, 1900–1998. Retrieved from http://www.cdc.gov/nchs/data/dvs/lead1900_98.pdf

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87–101. doi: 10.1016/J.Brainres.2012.02.068

Childs, E., & de Wit, H. (2014). Regular exercise is associated with emotional resilience to acute stress in healthy adults. *Frontiers in Physiology, 5*, 161. doi: 10.3389/Fphys.2014.00161

Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Medicine Reviews, 10*, 323–337. doi: 10.1016/J.Smrv.2005.11.001

DeLongis, A., Coyne, J. C., Dakof, G., Folkman, S., & Lazarus, R. S. (1982). Relationship of daily hassles, uplifts, and major life events to health status. *Health Psychology, 1*(2), 119–136.

Desmet, P. M. A., & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite, 50*, 290–301. doi: 10.1016/J.Appet.2007.08.003

Dewald, J. F., Meijer, A. M., Oort, F. J., Kerkhof, G. A., & Bogels, S. M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews, 14*, 179–189. doi: 10.1016/J.Smrv.2009.10.004

Ensel, W. M., & Lin, N. (2004). Physical fitness and the stress process. *Journal of Community Psychology, 32*, 81–101. doi: 10.1002/Jcop.10079

Ferreira, I., Twisk, J. W. R., Mechelen, W. van, Kemper, H. C. G., & Stehouwer, C. D. A. (2005). Development of fatness, fitness, and lifestyle from adolescence to the age of 36 years - Determinants of the metabolic syndrome in young adults: The Amsterdam Growth and Health Longitudinal Study. *Archives of Internal Medicine, 165*, 42–48. doi: 10.1001/Archinte.165.1.42

Flegal, K. M., Kit, B. K., Orpana, H., & Graubard, B. I. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories: A systematic review and meta-analysis. *JAMA, 309*, 71–82. doi: 10.1001/Jama.2012.113905

Forslund, H. B., Torgerson, J. S., Sjöström, L., & Lindroos, A.-K. (2005). Snacking frequency in relation to energy intake and food choices in obese men and women compared to a reference population. *International Journal of Obesity, 29*, 711–719. doi: 10.1038/sj.ijo.0802950

Galambos, N. L., Vargas Lascano, D. I., Howard, A. L., & Maggs, J. L. (2013). Who sleeps best? Longitudinal patterns and covariates of change in sleep quantity, quality, and timing across four university years. *Behavioral Sleep Medicine, 11*, 8–22. doi: 10.1080/15402002.2011.596234

Gall, T. L., Evans, D. R., & Bellerose, S. (2000). Transition to first-year university: Patterns of change in adjustment across life domains and time. *Journal of Social and Clinical Psychology, 19*, 544–567. doi: 10.1521/Jscp.2000.19.4.544

Garaulet, M., Ortega, F. B., Ruiz, J. R., Rey-Lopez, J. P., Beghin, L., Manios, Y., . . . Moreno, L. A. (2011). Short sleep duration is associated with increased obesity markers in European adolescents: Effect of physical activity and dietary habits. The HELENA study. *International Journal of Obesity, 35*, 1308–1317. doi: 10.1038/Ijo.2011.149

Gerber, M., & Puhse, U. (2009). Do exercise and fitness protect against stress-induced health complaints? A review of the literature. *Scandinavian Journal of Public Health, 37*, 801–819. doi: 10.1177/1403494809350522

Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences, 10* (3), 141–146.

Gomez-Pinilla, F. (2008). Brain foods: The effects of nutrients on brain function. *Nature Reviews Neuroscience, 9*, 568-578. doi: 10.1038/Nrn2421

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., & Workin, L. P. A. S. (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet, 380*, 247–257. doi: 10.1016/S0140-6736(12)60646-1

Harvey, A. G., Stinson, K., Whitaker, K. L., Moskovitz, D., & Virk, H. (2008). The subjective meaning of sleep quality: A comparison of individuals with and without insomnia. *Sleep, 31*(3), 383–393.

Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., . . . Bauman, A. (2007). Physical activity and public health - Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation, 116*, 1081–1093. doi: 10.1161/Circulationaha.107.185649

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*, 58–65. doi: 10.1038/Nrn2298

Hogan, C. L., Mata, J., & Carstensen, L. L. (2013). Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychology and Aging, 28*, 587–594. doi: 10.1037/a0032634

Hormes, J. M., & Rozin, P. (2011). The temporal dynamics of ambivalence: Changes in positive and negative affect in relation to consumption of an "emotionally charged" food. *Eating Behaviors, 12*, 219–221. doi: 10.1016/J.Eatbeh.2011.02.001

Hoyert, L. D., & Xu, J. (2012). Deaths: Preliminary data for 2011. In *National Vital Statistics Reports* (Vol. 61, pp. 1–52). Hyattsville, MD: National Center for Health Statistics.

Irwin, J. D. (2004). Prevalence of university students' sufficient physical activity: A systematic review. *Perceptual and Motor Skills, 98*(3), 927–943.

Jacobs, N., Myin-Germeys, I., Derom, C., Delespaul, P., Os, J. v., & Nicolson, N. A. (2007). A momentary assessment study of the relationship between affective and

adrenocortical stress responses in daily life. *Biological Psychology, 74*, 60–66. doi: 10.1016/J.Biopsycho.2006.07.002

Kahn, M., Sheppes, G., & Sadeh, A. (2013). Sleep and emotions: Bidirectional links and underlying mechanisms. *International Journal of Psychophysiology, 89*, 218–228. doi: 10.1016/J.Ijpsycho.2013.05.010

Kanning, M. K., Ebner-Priemer, U. W., & Schlicht, W. M. (2013). How to investigate within-subject associations between physical activity and momentary affective states in everyday life: A position statement based on a literature overview. *Frontiers in Psychology, 4*, 1–16. doi: 10.3389/fpsyg.2013.00187

Keast, D. R., Nicklas, T. A., & O'Neil, C. E. (2010). Snacking is associated with reduced risk of overweight and reduced abdominal obesity in adolescents: National Health and Nutrition Examination Survey (NHANES) 1999–2004. *American Journal of Clinical Nutrition, 92*, 428–435. doi: 10.3945/Ajcn.2009.28421

Keating, X. F. D., Guan, J. M., Pinero, J. C., & Bridges, D. M. (2005). A meta-analysis of college students' physical activity behaviors. *Journal of American College Health, 54*, 116–125. doi: 10.3200/Jach.54.2.116-126

King, A. C., Castro, C. M., Buman, M. P., Hekler, E. B., Urizar, G. G., & Ahn, D. K. (2013). Behavioral impacts of sequentially versus simultaneously delivered dietary plus physical activity interventions: The CALM Trial. *Annals of Behavioral Medicine, 46*, 157–168. doi: 10.1007/S12160-013-9501-Y

Klaperski, S., Seelig, H., & Fuchs, R. (2012). Physical activity as a stress buffer. *Zeitschrift für Sportpsychologie [Journal of Physical Activity in Psychology], 19*, 80–90. doi: 10.1026/1612-5010/A000061

Kwan, M. Y., Cairney, J., Faulkner, G. E., & Pullenayegum, E. E. (2012). Physical activity and other health-risk behaviors during the transition into early adulthood: A

longitudinal cohort study. *American Journal of Preventive Medicine, 42*, 14–20. doi: 10.1016/J.Amepre.2011.08.026

Lazarus, R.S., & Folkman, S. (1984). *Stress, appraisal, and coping*. New York, NY: Springer.

Lucke, J., & Partridge, B. (2013). Towards a smart population: A public health framework for cognitive enhancement. *Neuroethics, 6*, 419–427. doi: 10.1007/s12152-012-9167-3

Lund, H. G., Reider, B. D., Whiting, A. B., & Prichard, J. R. (2010). Sleep patterns and predictors of disturbed sleep in a large population of college students. *Journal of Adolescent Health, 46*, 124–132. doi: 10.1016/J.Jadohealth.2009.06.016

Lyubomirsky, S., King, L., & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin, 131*, 803–855. doi: 10.1037/0033-2909.131.6.803

Lyubomirsky, S., Sheldon, K. M., & Schkade, D. (2005). Pursuing happiness: The architecture of sustainable change. *Review of General Psychology*, *9*, 111–131. doi: 10.1037/1089-2680.9.2.111

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual Review of Psychology, 58*, 593–614. doi: 10.1146/annurev.psych.58.110405.085542

Maier, L. J., Liechti, M. E., Herzig, F., & Schaub, M. P. (2013). To dope or not to dope: Neuroenhancement with prescription drugs and drugs of abuse among Swiss university students. *PLOS ONE, 8*(11), e77967.

Marmeleira, J. (2013). An examination of the mechanisms underlying the effects of physical activity on brain and cognition. *European Review of Aging and Physical Activity, 10*, 83–94. doi: 10.1007/S11556-012-0105-5

Mastin, D. F., Bryson, J., & Corwyn, R. (2006). Assessment of sleep hygiene using the sleep hygiene index. *Journal of Behavioral Medicine, 29*, 223–227. doi: 10.1007/S10865-006-9047-6

Mata, J., Hogan, C. L., Joormann, J., Waugh, C. E., & Gotlib, I. H. (2013). Acute exercise attenuates negative affect following repeated sad mood inductions in persons who have recovered from depression. *Journal of Abnormal Psychology, 122*, 45–50. doi: 10.1037/A0029881

Mata, J., Silva, M. N., Vieira, P. N., Carraca, E. V., Andrade, A. M., Coutinho, S. R., . . . Teixeira, P. J. (2009). Motivational "spill-over" during weight control: Increased self-determination and exercise intrinsic motivation predict eating self-regulation. *Health Psychology, 28*, 709–716. doi: 10.1037/A0016764

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gottlib, I. H. (2012). Walk on the bright side: Physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*, 297–308. doi: 10.1037/a0023533

Mattli, R., Hess, S., Maurer, M., Eichler, K., Pletscher, M., & Wieser, S. (2014). Kosten der körperlichen Inaktivität in der Schweiz: Schlussbericht [Costs of physical inactivity in Switzerland: Final report]. Zürich, Schweiz: Zürcher Hochschule für Angewandte Wissenschaften.

Miller, R., Benelam, B., Stanner, S., & Buttriss, J. (2013). Is snacking good or bad for health: An overview. *Nutrition Bulletin, 38*, 302–322. doi: 10.1111/nbu.12042

Miner, A. G., & Glomb, T. M. (2010). State mood, task performance, and behavior at work: A within-persons approach. *Organizational Behavior and Human Decision Processes, 112*, 43–57. doi: 10.1016/J.Obhdp.2009.11.009

Molenaar, P. C. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement, 2*, 201–218. doi: 10.1207/s15366359mea0204_1

Morisano, D., Hirsh, J. B., Peterson, J. B., Pihl, R. O., & Shore, B. M. (2010). Setting, elaborating, and reflecting on personal goals improves academic performance. *Journal of Applied Psychology, 95*, 255–264. doi: 10.1037/A0018478

Morrell, J. S., Lofgren, I. E., Burke, J. D., & Reilly, R. A. (2012). Metabolic syndrome, obesity, and related risk factors among college men and women. *Journal of American College Health, 60*, 82–89. doi: 10.1080/07448481.2011.582208

National Sleep Foundation. (2015). How much sleep do we really need? Retrieved from http://sleepfoundation.org/how-sleep-works/how-much-sleep-do-we-really-need

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., . . . Gakidou, E. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *Lancet, 384*, 766–781. doi: 10.1016/S0140-6736(14)60460-8

Nikolaou, C., Hankey, C., & Lean, M. (2014). Weight changes in young adults: A mixed-methods study. *International Journal of Obesity, 39*, 508–513. doi: 10.1038/ijo.2014.160

Nocon, M., Hiemann, T., Muller-Riemenschneider, F., Thalau, F., Roll, S., & Willich, S. N. (2008). Association of physical activity with all-cause and cardiovascular mortality: A systematic review and meta-analysis. *European Journal of Cardiovascular Prevention and Rehabilitation: Official Journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology, 15*, 239–246. doi: 10.1097/HJR.0b013e3282f55e09

Norris, R., Carroll, D., & Cochrane, R. (1992). The effects of physical-activity and exercise training on psychological stress and well-being in an adolescent population. *Journal of Psychosomatic Research, 36*, 55–65. doi: 10.1016/0022-3999(92)90114-H

Ogden, J. (2010). *Health psychology: A textbook. 5th edition.* New York, NY: Open University Press.

Oldridge, N. B. (2008). Economic burden of physical inactivity: healthcare costs associated with cardiovascular disease. *European Journal of Cardiovascular Prevention and Rehabilitation: Official Journal of the European Society of Cardiology, Working*

Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology, 15, 130–139. doi: 10.1097/HJR.0b013e3282f19d42

Omran, A. R. (1971). The epidemiologic transition. A theory of the epidemiology of population change. *The Milbank Memorial Fund, 49*(4), 509–538.

Organisation for Economic Co-operation and Development. (2012). Education at a glance 2012: Highlights. Retrieved from http://www.uis.unesco.org/Education/Documents/oecd-eag-2012-en.pdf

Organisation for Economic Co-operation and Development. (2013). Education at a glance 2013: OECD indicators. Retrieved from http://dx.doi.org/10.1787/eag-2013-en

Organisation for Economic Co-operation and Development. (2014). Education at a glance 2014: OECD indicators. Retrieved from http://dx.doi.org/10.1787/eag-2014-en

Piernas, C., & Popkin, B. M. (2010). Snacking increased among US adults between 1977 and 2006. *The Journal of Nutrition, 140*, 325–332. doi: 10.3945/jn.109.112763

Pilcher, J. J., Ginter, D. R., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: Relationships between sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research, 42*(6), 583–596.

Polivy, J., & Herman, C. P. (2005). Mental health and eating behaviours: A bi-directional relation. *Canadian Journal of Public Health, 96*, S43–S46.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods Instruments & Computers, 36*, 717–731. doi: 10.3758/Bf03206553

Rasch, B., & Born, J. (2013). About sleep's role in memory. *Physiological Reviews, 93*, 681–766. doi: 10.1152/Physrev.00032.2012

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage Publications.

Reed, J., & Buck, S. (2009). The effect of regular aerobic exercise on positive-activated affect: A meta-analysis. *Psychology of Sport and Exercise, 10*, 581–594. doi: 10.1016/J.Psychsport.2009.05.009

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise, 7*, 477–514. doi: 10.1016/J.Psychsport.2005.11.003

Rejeski, W. J., Thompson, A., Brubaker, P. H., & Miller, H. S. (1992). Acute exercise - Buffering psychosocial stress responses in women. *Health Psychology, 11*, 355–362. doi: 10.1037//0278-6133.11.6.355

Richard, E. M., & Diefendorff, J. M. (2011). Self-regulation during a single performance episode: Mood-as-information in the absence of formal feedback. *Organizational Behavior and Human Decision Processes, 115*, 99–110. doi: 10.1016/J.Obhdp.2010.11.008

Richardson, M., Abraham, C., & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin, 138*, 353–387. doi: 10.1037/A0026838

Riemann, D., & Backhaus, J. (1996). *Behandlung von Schlafstörungen [Treatment of sleep disorders]*. Weinheim, Germany: Beltz Psychologie-Verlag-Union.

Roecke, C. (2006). *Intraindividual variability in positive and negative affect.* Doctoral dissertation, Free University Berlin, Germany. Retrieved from http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002464

Roecke, C., Li, S. C., & Smith, J. (2009). Intraindividual variability in positive and negative affect over 45 days: Do older adults fluctuate less than young adults? *Psychology and Aging, 24*, 863–878. doi: 10.1037/a0016276

Santosa, A., Wall, S., Fottrell, E., Hogberg, U., & Byass, P. (2014). The development and experience of epidemiological transition theory over four decades: A systematic review. *Global Health Action, 7*, 23574. doi: 10.3402/gha.v7.23574

Schubert, M. M., Desbrow, B., Sabapathy, S., & Leveritt, M. (2013). Acute exercise and subsequent energy intake: A meta-analysis. *Appetite, 63*, 92–104. doi: 10.1016/J.Appet.2012.12.010

Schwabe, L., Joels, M., Roozendaal, B., Wolf, O. T., & Oitzl, M. S. (2012). Stress effects on memory: An update and integration. *Neuroscience and Biobehavioral Reviews, 36*, 1740–1749. doi: 10.1016/j.neubiorev.2011.07.002

Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry, 14*, 296–303. doi: 10.1207/S15327965pli1403&4_20

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology, 4*(1), 1-32.

Simor, P., Krietsch, K. N., Koteles, F., & McCrae, C. S. (2015). Day-to-day variation of subjective sleep quality and emotional states among healthy university students: A 1-week prospective study. *International Journal of Behavioral Medicine*. doi: 10.1007/s12529-015-9464-4

Small, M., Bailey-Davis, L., Morgan, N., & Maggs, J. (2013). Changes in eating and physical activity behaviors across seven semesters of college: Living on or off campus matters. *Health Education & Behavior, 40*, 435–441. doi: 10.1177/1090198112467801

Sonnentag, S., Binnewies, C., & Mojza, E. J. (2008). "Did you have a nice evening?" A day-level study on recovery experiences, sleep and affect. *Journal of Applied Psychology, 93*, 674–683. doi: 10.1037/0021-9010.93.3.674

Steenhuis, I. (2009). Guilty or not? Feelings of guilt about food among college women. *Appetite, 52*, 531–534. doi: 10.1016/J.Appet.2008.12.004

Steptoe, A., Wardle, J., Pollard, T. M., Canaan, L., & Davies, G. J. (1996). Stress, social support and health-related behavior: A study of smoking, alcohol consumption and physical exercise. *Journal of Psychosomatic Research, 41*, 171–180. doi: 10.1016/0022-3999(96)00095-5

Strohle, A., Hofler, M., Pfister, H., Muller, A. G., Hoyer, J., Wittchen, H. U., & Lieb, R. (2007). Physical activity and prevalence and incidence of mental disorders in adolescents and young adults. *Psychological Medicine, 37*, 1657–1666. doi: 10.1017/S003329170700089x

Stubbs, R. J., O'Reilly, L. M., Whybrow, S., Fuller, Z., Johnstone, A. M., Livingstone, M. B. E., . . . Horgan, G. W. (2014). Measuring the difference between actual and reported food intakes in the context of energy balance under laboratory conditions. *British Journal of Nutrition, 111*, 2032–2043. doi: 10.1017/S0007114514000154

Thoits, P. A. (2010). Stress and health: Major findings and policy implications. *Journal of Health and Social Behavior, 51*, 41–53. doi: 10.1177/0022146510383499

Vella-Zarb, R. A., & Elgar, F. J. (2009). The 'Freshman 5': A Meta-Analysis of Weight Gain in the Freshman Year of College. *Journal of American College Health, 58*(2), 161-166.

Wald, A., Muennig, P. A., O'Connell, K. A., & Garber, C. E. (2014). Associations between healthy lifestyle behaviors and academic performance in U.S. undergraduates: A secondary analysis of the American College Health Association's National College Health Assessment II. *American Journal of Health Promotion, 28*, 298–305. doi: 10.4278/ajhp.120518-QUAN-265

Walls, T. A., & Schafer, J. L. (Eds.). (2006). *Models for intensive longitudinal data*. New York, NY: Oxford University Press.

Walsh, R. (2011). Lifestyle and mental health. *American Psychologist, 66*, 579–592. doi: 10.1037/A0021769

Watson, D. (2000). Mood and temperament. In D. Watson (Ed.), *An introduction to the study of mood and temperament* (pp. 62–103). New York, NY: Guilford Press.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070. doi: 10.1037/0022-3514.54.6.1063

Wilcox, S., King, A. C., Castro, C., & Bortz, W. (2000). Do changes in physical activity lead to dietary changes in middle and old age? *American Journal of Preventive Medicine, 18*, 276–283. doi: 10.1016/S0749-3797(00)00117-3

Wong, M. L., Lau, E. Y. Y., Wan, J. H. Y., Cheung, S. F., Hui, C. H., & Mok, D. S. Y. (2013). The interplay between sleep and mood in predicting academic functioning, physical health and psychological health: A longitudinal study. *Journal of Psychosomatic Research, 74*(4), 271–277.

World Health Organization. (1946). *WHO definition of health.* Paper presented at the International Health Conference, New York.

World Health Organization. (1986). Ottawa Charter for Health Promotion. Retrieved from http://www.who.int/healthpromotion/conferences/previous/ottawa/en/

World Health Organization. (2002). *The world health report 2002: Reducing risks, promoting healthy life*. Geneva, Switzerland: Author.

World Healh Organization. (2009). Global health risks: Mortality and burden of disease attributable to selected major risks. Retrieved from http://www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf

World Health Organization. (2015a). Cancer (Fact sheet no. 297). Retrieved from http://www.who.int/mediacentre/factsheets/fs297/en/

World Health Organization. (2015b). Risk factors. Retrieved from http://www.who.int/cardiovascular_diseases/en/cvd_atlas_03_risk_factors.pdf?ua=1

Zizza, C., Siega-Riz, A. M., & Popkin, B. M. (2001). Significant increase in young adults' snacking between 1977–1978 and 1994–1996 represents a cause for concern! *Preventive Medicine, 32*, 303–310. doi: 10.1006/Pmed.2000.0817

Appendices A – D

Appendix A

Flueckiger, L., Lieb, R., Meyer, A., & Mata, J. (2014). How health behaviors relate to academic performance via affect: An intensive longitudinal study. *PLOS ONE*, 9, e111080. doi: 10.1371/journal.pone.0111080

Appendix B

Flueckiger, L., Lieb, R., Meyer, A., Witthauer, C., & Mata, J. (under review in *Health Psychology*). Day-to-day variations in health behaviors and daily functioning: Two intensive longitudinal studies.

Appendix C

Flueckiger, L., Lieb, R., Meyer, A., Witthauer, C., & Mata, J. (submitted to *Emotion*). The importance of physical activity and sleep for affect on stressful days: Two intensive longitudinal studies.

Appendix D

Curriculum Vitae

Appendix A

How Health Behaviors Relate to Academic Performance via Affect:

An Intensive Longitudinal Study

Flueckiger, L., Lieb, R., Meyer, A., & Mata, J. (2014)

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How Health Behaviors Relate to Academic Performance via Affect: An Intensive Longitudinal Study

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Abstract

Objective: This intensive longitudinal study examined how sleep and physical activity relate to university students' affect and academic performance during a stressful examination period.

Methods: On 32 consecutive days, 72 first-year students answered online questionnaires on their sleep quality, physical activity, positive and negative affect, learning goal achievement, and examination grades. First-year university students are particularly well-suited to test our hypotheses: They represent a relatively homogeneous population in a natural, but controlled setting, and simultaneously deal with similar stressors, such as examinations. Data were analyzed using multilevel structural equation models.

Results: Over the examination period, better average sleep quality but not physical activity predicted better learning goal achievement. Better learning goal achievement was associated with increased probability of passing all examinations. Relations of average sleep quality and average physical activity with learning goal achievement were mediated by experienced positive affect. In terms of day-to-day dynamics, on days with better sleep quality, participants reported better learning goal achievement. Day-to-day physical activity was not related to daily learning goal achievement. Daily positive and negative affect both mediated the effect of day-to-day sleep quality and physical activity on daily learning goal achievement.

Conclusion: Health behaviors such as sleep quality and physical activity seem important for both academic performance and affect experience, an indicator of mental health, during a stressful examination period. These results are a first step toward a better understanding of between- and within-person variations in health behaviors, affect, and academic performance, and could inform prevention and intervention programs for university students.

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Data Availability: The authors confirm that all data underlying the findings are fully available without restriction. All Dataset files related to our manuscript are now available form the Harvard Dataverse Network database (?http://thedata.harvard.edu/dvn/dv/healthbehav).

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Introduction

Starting university is an academically and socially challenging transition; the university years are often considered the most demanding learning period in many people's lives. About a third of students entering university-level education leave without a degree [1]. Concerning study duration, on average students take a good semester longer to graduate than recommended [2]. The consequences of university dropout or prolonged study duration include increased education costs [3] and unfulfilled dreams—for example, not having the qualifications to work in one's chosen profession or earning a lower salary [1].

Therefore, identifying behaviors that can help young adults to achieve their academic goals is of considerable importance. This prospective longitudinal study investigated whether health behaviors, such as sleep and physical activity, are related to academic performance in young adults. Specifically, we examined both, average values across the entire study period as well as day-to-day dynamic relations. We tested how sleep quality and physical activity were related to learning goal achievement and, in turn, whether average learning goal achievement predicted success in year-end examinations. Furthermore, we tested whether positive and negative affect mediated the relations of sleep quality and physical activity with learning goal achievement.

Health behaviors and academic performance

Health behaviors such as sleep and physical activity have been associated with increased cognitive performance and better grades [4,5]. A meta-analytic review has demonstrated that better overall sleep quality and longer sleep duration in children and adolescents are related to better grades [4]. Additionally, a review by Curcio, Ferrara, and De Gennaro [6] has shown that poor overall sleep

quality in students from school to university is associated with impairment of cognitive performance, reduced learning behavior, and weaker academic performance. Likewise, Ahrberg, Dresler, Niedermaier, Steiger, and Genzel [7] found that higher sleep quality prior to examinations (but not during the semester or after the examination period) was linked to better academic performance in a sample of university students.

Concerning the role of physical activity, it has consistently been shown that acute aerobic activity is related to improvements in cognitive performance [5]. Importantly, high levels of regular physical activity have been associated with better grades [8–10] and higher self-perceived overall academic performance in children and adolescents [11,12]. Importantly, the existing literature has focused on the association of sleep and physical activity with academic performance on the between-person level.

Affect as a potential mechanism underlying the association between health behaviors and academic performance

Several physiological mechanisms have been suggested as underlying the relation between health behaviors such as physical activity and cognitive performance, including improvement in oxygen consumption [13], increased task-related brain activity [14,15], and increased brain volume in the prefrontal and temporal cortices in older adults [16]. Patterns of activation in prefrontal cortex have also been suggested as an underlying mechanism for the relation between sleep and cognitive performance [17]. Potential psychological mechanisms have received less attention.

One plausible psychological mechanism is affect: Positive affect is associated with successful outcomes in various life domains, including health and academic performance [18,19]. Specifically, affect has been demonstrated to influence different aspects of learning behavior, motivation [20] and achievement [21]. In recent years, researchers have started to test the link between affect and learning behavior at the within-person level. When immediate feedback is absent, as is the case when students study for a major exam over several weeks, current affect may be used as input for setting learning goals [22] as well as on goal achievement and progress judgment [23]. This idea is in line with the mood-as-information model by Schwarz and Clore [24], which claims that current affect serves as a source of information for judgments. Richard and Diefendorff [22] observed that higher positive affect in university students predicted higher learning goals the next day, whereas higher negative affect predicted lower learning goals the next day. Likewise, in a sample of employees, Miner and Glomb [25] showed that periods of positive affect were associated with periods of improved task performance.

The empirical evidence also indicates that sleep and physical activity influence affect on the between- and within-person level. A meta-analysis and reviews have shown that sleep deprivation adversely impacts affect [26–28]. As a potential underlying mechanism for the relation between sleep and affect, it has been suggested that sleep deprivation leads the prefrontal cortex region to inhibit the amygdala, a brain structure that is crucial for the generation and recognition of affect [29]. However, few studies have demonstrated that increased sleep quality predicts increased positive affect on a between-person [30] or a within-person level [31,32]. Other studies have shown that being physically active predicts higher positive and lower negative affect [33,34], and meta-analyses have suggested that acute as well as regular aerobic exercise produces increases in positive affect [35,36]. For these beneficial effects of physical activity on affect, several potential psychological and physiological mechanisms have been discussed, including the distraction hypothesis, self-efficacy theory, as well as the endorphin and monoamin hypothesis [37].

Importantly, young adulthood is not only a time of academic challenges, but also a critical period for the onset of mental illnesses such as mood and anxiety disorders [38,39]. Specifically, the first year of university is a critical time for the first occurrence of depressive symptoms [40]. Identifying behaviors that impact affect experience in this period is therefore particularly important. Given the previous findings on health behaviors influencing affect and on the involvement of affect in academic performance, it is plausible that health behaviors might influence academic performance through changes in affect.

Academic performance

Academic performance in tertiary education is a construct that has been assessed on different dimensions, including intelligence, cognitive capacity, and examination success [41,42]. However, examination success is the key requirement for continuation of studies and graduate employment [43] and therefore, examination success and grades are still the most widespread performance measures [44]. Research has shown that self-regulatory learning strategies [44,45] as well as goal setting [46] predict better grades. Self-regulation may be particularly important for maintaining the motivation of learners pursuing long-term goals without immediate performance feedback - as is the case for students studying for major examinations [47]. Therefore, the achievement of students' self-set learning goals may predict examination success.

Hypotheses

To our knowledge, no previous study has combined health behaviors, affect, and academic performance within a single model and evaluated their relations on a between-person level as well as at the level of day-to-day dynamics. Based on the theoretical foundations, including direction of associations, reviewed above, we test the following hypotheses (see also Figure 1):

Between-person level. (1a) Better average sleep quality predicts better average learning goal achievement; higher average physical activity predicts better average learning goal achievement.

(1b) Average positive/negative affect mediates the relation between average sleep quality and average learning goal achievement (e.g., higher average sleep quality predicts higher positive affect which in turn predicts better average learning goal achievement). Likewise, average positive/negative affect mediates the relation between average physical activity and average learning goal achievement.

(1c) Students who on average report better learning goal achievement are more likely to pass their examinations.

Day-to-day level (within-person level). (2a) On days on which students report higher sleep quality, they also report better learning goal achievement; on days on which students report higher physical activity, they also report better learning goal achievement.

(2b) Daily positive/negative affect mediates the relation between sleep quality and learning goal achievement as well as the relation between physical activity and learning goal achievement (e.g., on days with higher sleep quality, students experience higher positive affect which in turn predicts better learning goal achievement).

Methods

Design

Data were obtained from a prospective, intensive longitudinal survey. First-year psychology students from the University Basel, answered online questionnaires during 46 consecutive days over

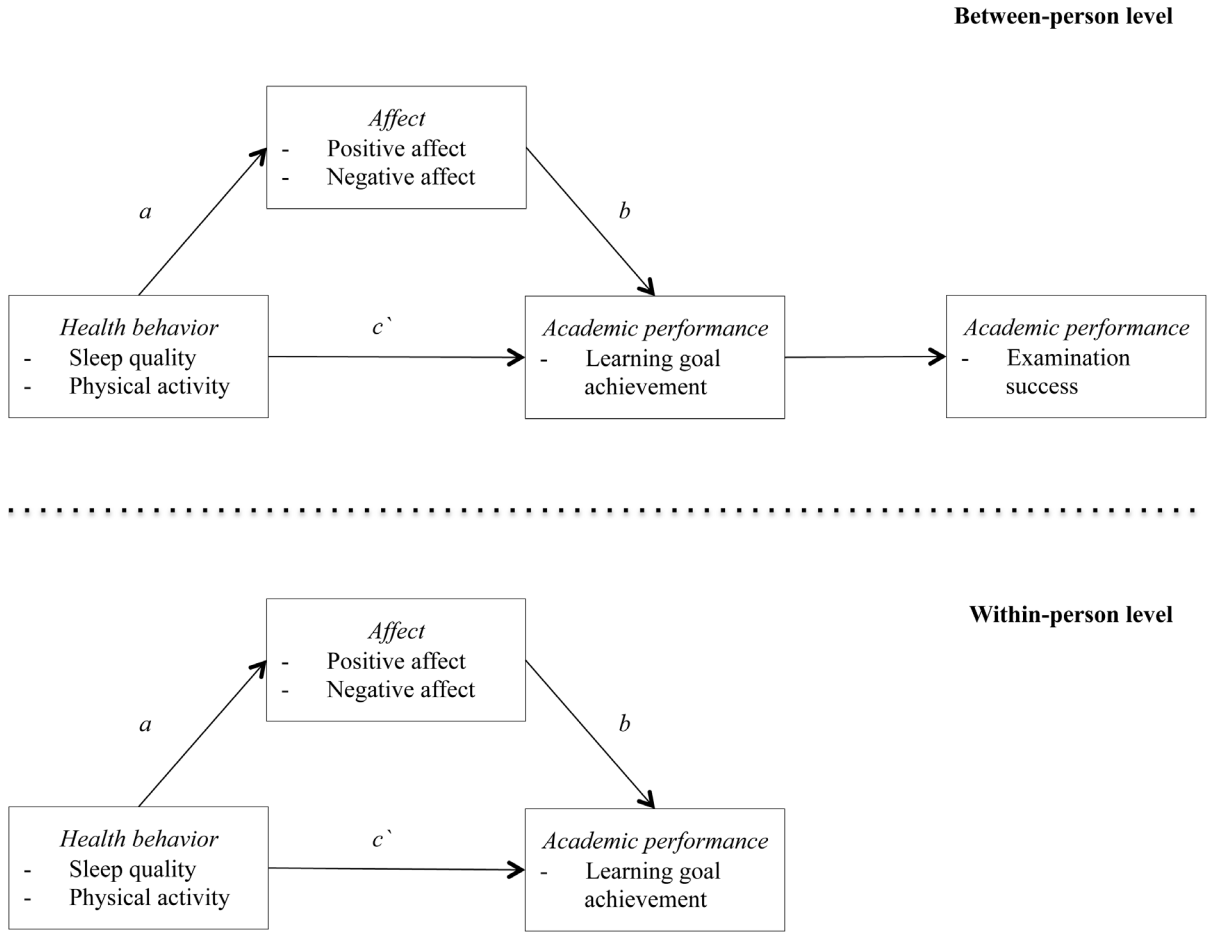

Figure 1. Mediation model of health behaviors on academic performance via affect on between- and within-person level.
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the year-end examination period from May to July 2011. The first 14 days involved examination preparation; the following 18 days were the examination period proper; and the last 14 days were the post-examination period. Because this article aims to understand behavior and experience during the preparation phase and to predict examination success, only data collected during the first 32 days were used in the present analyses. Participants sat six examinations that are obligatory for all first-year psychology students at the University of Basel. Importantly, students failing at least one of these examinations more than once are excluded from studying psychology at any Swiss university.

Participants

First-year university students were chosen as participants for this study because for several reasons they are a particularly well-suited population to test our hypotheses: For one, they simultaneously have to deal with the same stressors, such as final examinations, thus they are in a natural, but relatively controlled setting. Second, most students are of similar age and education background, thus, they represent a comparably homogeneous population. Third, all university students receive Internet access through the university, thus conducting an online study does not lead to selection biases. The original sample consisted of 82 first-year psychology students from the University of Basel, who volunteered to participate in the study (142 students were enrolled as first year psychology students at the University of Basel at the time). Five participants did not take the final examinations and an additional five participants did not state their examination grades. These ten participants were excluded from the analyses, leaving a final sample of $N = 72$ (see Table 1 for sample characteristics). The ten excluded participants did not significantly differ from the 72 remaining participants in any of the variables of interest. There were no significant differences between men and women in any of the sample characteristics reported in Table 1 except for negative affect. Women reported higher negative affect compared to men $M = 2.74$, $SD = 0.95$ versus $M = 1.94$, $SD = 0.70$, $t(11.23) = 2.85$, $p = .016$. The 72 participants completed daily questionnaires and delivered a total of 2111 responses over the 32 days, giving $M = 29.3$ completed questionnaires per person ($SD = 5.04$; range: 8–32 questionnaires per person) which represents a compliance rate of 92%.

Procedure

The ethics committee "Ethikkommission Nordwest- und Zentralschweiz (EKNZ)" approved the current study (Ref.Nr. EK: 48/11). Participants were recruited through announcements during first-year psychology lectures at the University of Basel. Interested students received an email with a link to the website of the online entry questionnaire, where they were given detailed information about the study. After giving written consent, participants received an email every day at 5 pm for 32 consecutive days. The email contained a link to that day's online

Table 1. Sample characteristics.

Characteristic	Total sample (*N* = 72)
Gender (women %)	70.1%
Age (median in years)	21.0
Number of semesters studied (median)	2.0
Learning goal achievement (*M, SD*)	2.2 (1.1)
Sleep quality (*M, SD*)	3.0 (0.8)
Physical activity (median)	180
Positive affect (*M, SD*)	4.2 (1.6)
Negative affect (median)	2.3

Note. Learning goal achievement was rated on a 5-point Likert scale from 0 (not at all) to 4 (completely); *sleep quality* was rated on a 4-point Likert scale from 1 (very bad) to 4 (very good); minutes of mild, moderate and strenuous *physical activity* were converted into metabolic equivalents; experiencing *positive and negative affect* was rated on a 7-point Likert scale from 1 (not at all) to 7 (extremely).
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questionnaire. At the end of the examination period, they completed an online exit questionnaire.

In each day's questionnaire, participants were asked to enter their personal code (made up of letters from their mother's first name, maiden name, and birthday). This code was used to link each participant's questionnaires. Participants were never asked to enter any information that would make it possible to identify them; responses to the questionnaires and email addresses could not be linked. On average, answering one daily questionnaire took 4.1 ($SD = 4.3$) minutes. Students could choose between receiving financial compensation of up to 50 Swiss Francs, corresponding to approximately 55 US-Dollars, for participation or equivalent course credits in psychology; the exact level of compensation was dependent on the number of questionnaires completed.

Measures

Entry and Exit Questionnaire. *Sociodemographic variables* were assessed in the entry questionnaire (see Table 1). The measure of *academic performance* on the between-person level, examination success, was calculated from the grades of the six final examinations that participants took. Participants reported the grades of these independent examinations in the exit-questionnaire. Internal consistency reliability for the grades of these six examinations was Cronbach's $\alpha = .89$. It is important to note that these six grades are the only criterion used to decide whether a student can continue studying psychology. Even if they fail only one of these six examinations more than once, they are excluded from studying psychology at any Swiss university. This variable was dichotomized into pass and fail, as students must pass *all* six examinations to continue their study. Thus, examination grades are the only parameter to determine academic success in the first year at university. Further, to determine external validity of the examination grades, high school grades between students who failed the first year examinations were compared to students' high school grades who passed. Various studies have shown that high school grades are a strong predictor of academic performance [48] and high school performance has been used as a measure to determine scholastic aptitude in university students, when standardized tests are not available [21]. Participants who passed all six examinations reported significantly better average high school grades than participants who did not pass all six examinations, $M = 4.84$, $SD = 0.45$ versus $M = 4.53$, $SD = 0.39$, respectively, where higher numbers represent better high school performance; $t(66) = -3.12$, $p = .003$.

Daily Questionnaire. *Daily sleep quality* was assessed with the item from the German version of the Pittsburgh Sleep Quality Index [49] which has been shown to have the highest correlation between a single-item and the final score of the full scale (single item – total correlation), $r = 0.83$ [50]. Specifically, participants rated their sleep quality during the previous night on a 4-point Likert scale from 1 (very bad) to 4 (very good).

Physical activity was evaluated with the Godin Leisure-Time Exercise Questionnaire [51], adapted to the daily online questionnaire format [34]. Participants were instructed to report their physical activity during the last 24 hours in terms of the number of minutes engaged in mild (minimal effort; e.g., easy walking), moderate (not exhausting; e.g., fast walking), and strenuous exercise (heart beats rapidly; e.g., running). The daily minutes of mild, moderate, and strenuous exercise were weighted by metabolic equivalents and then summed to produce a total daily leisure activity score. High scores reflect high levels of physical activity [51]. The original Godin Leisure-Time questionnaire has been found to have adequate concurrent validity with accelerometry and with maximum oxygen consumption [52].

Daily positive and negative affect were assessed with the German version of the pleasantness scale [53], a six-item instrument that has been shown to lead to comparable results as the Positive and Negative Affect Schedule (PANAS) [54] in a non-clinical sample [53]. Participants indicated the extent to which they had experienced each of the following six emotions during the last 24 hours on a 7-point Likert scale from 1 (not at all) to 7 (extremely): happy, content, cheerful, sad, downhearted, and frustrated. Internal consistency reliabilities were $\alpha = .95$ ($M = 13.35$, $SD = 4.83$) for positive affect and $\alpha = .87$ ($M = 7.37$, $SD = 4.31$) for negative affect calculated for all 32 measurement occasions.

As an additional measure of *academic performance* next to examination success, daily learning goal achievement was assessed on a day-to-day-level. Participants were asked whether they had achieved the learning goals they had set themselves for the previous 24 hours on a 5-point Likert scale from 0 (not at all) to 4 (completely) [22]. Importantly, examinations in the current study took place towards the end of the study period. Thus, examination success could not be used as a measure of academic performance during the entire period of studying towards the exams. Therefore, to understand the daily dynamics of academic performance during the study phase, learning goal achievement was measured daily, which is closely related to examination success [20].

Statistical analyses

We used multilevel structural equation models, which are suitable for analyzing the nested structure of repeated measures data, and which handle missing data and varying time intervals in an appropriate way [55,56]. We used a two-level model, with measurements nested within participants. Multilevel structural equation models, an extension to multilevel mediation models, have been shown to lead to unconflated estimates of between- and within-level components of indirect effects, thereby avoiding the biased estimates that can occur with more traditional multilevel models [55]. In multilevel structural equation models, person-mean centering is used by default. That is, the variables on the within-person level denote deviations from each individual's mean (e.g., individual learning goal achievement on days with high vs. low sleep quality). There is an implicit partitioning of the observed variables into latent within and between components. Here, we used a fixed slopes model in which only intercepts, but not slope parameters, were allowed to vary between individuals.

The mediation hypotheses on the between-person level as well as on the day-to-day level were analyzed in four distinct models, separately for the two predictors sleep quality and physical activity and for the two mediators positive and negative affect. Hence, each of our multilevel structural equation models contained one predictor, one mediator, and one outcome variable. This allowed us to test Hypotheses 1 and 2 for each predictor–mediator–outcome triplet (see Figure 1). We did not include all variables of interest within the same model, to avoid problems with overfitting [57]. Because examination success could be assessed only once at the end of the academic year, it was integrated in the between-person model, but could not be implemented in the within-person model, which is based on multiple measurements of each construct. To compare the results concerning the day-to-day dynamics of the within-person model with the average levels of the between-person model, we tested identical models on the within- and between-person level: Both models tested the relation between health behaviors, affect, and academic performance. In addition, examination success was added as outcome to the between-person model. To account for the expected nonlinear trend of learning goal achievement and affect over time, we included a temporal linear, quadratic, and cubic term in the model. As physical activity and negative affect were not normally distributed, they were transformed to approximate a normal distribution. We used Mplus (version 6.12) for the multilevel structural equation models and R (R version 2.15.1) for the remaining analyses.

Results

Descriptive statistics of the variables of interest are presented in Table 1. In general, participants reported considerably high sleep quality and there was a large variability in physical activity. Participants also reported medium learning goal achievement as well as relatively high positive and relatively low negative affect. Forty-seven percent of the participants passed all six examinations.

Between-person level

Hypothesis 1a: Association of sleep quality and physical activity with learning goal achievement (total effects). Supporting our hypothesis, students with higher average sleep quality reported better learning goal achievement ($c = 11.03$, $SE = 1.35$, $p < .001$; see Table 2 for all results). However, there was no significant association between physical activity and learning goal achievement ($c = 0.30$, $SE = 0.17$, $p = .079$).

Table 2. Direct, total, and mediated effects of sleep quality and physical activity on learning goal achievement via positive and negative affect on a between-person level.

Predictor	Sleep quality Positive affect		Sleep quality Negative affect		Physical activity Positive affect		Physical activity Negative affect	
Mediator								
	B (*SE*)	*p*	*B* (*SE*)	*p*	*B* (*SE*)	*p*	*B* (*SE*)	*p*
a	19.84 (3.43)	<.001	−5.74 (1.08)	<.001	0.87 (0.17)	<.001	−0.19 (0.07)	.007
b	0.15 (0.05)	.007	−0.16 (0.19)	.385	0.30 (0.05)	<.001	−0.66 (0.19)	.001
ab (indirect effect)	2.91 (1.19)	.014	0.94 (1.09)	.385	0.27 (0.07)	<.001	0.13 (0.07)	.051
Mediated proportion (%)	26%		8.5%		88%		42%	
c (total effect)	11.03 (1.35)	<.001	11.05 (1.36)	<.001	0.30 (0.17)	.079	0.30 (0.17)	.081
c′ (direct effect)	8.12 (1.81)	<.001	10.11 (1.90)	<.001	0.04 (0.18)	.839	0.17 (0.18)	.346

Note. Ratios are based on absolute values of direct and indirect effects, e.g. positive affect mediated 26% of the total effect between sleep quality and learning goal achievement. *a* = path from predictor to mediator; *b* = path from mediator to outcome;
B = unstandardized regression coefficient; *c* = *ab* (indirect effect) + *c′* (direct effect); *c′* = path from predictor to outcome after controlling for the mediator; *SE* = standard error.
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Hypothesis 1b: Positive and negative affect as mediators (indirect and direct effects). The relation between average sleep quality and average learning goal achievement was partially mediated by positive affect (see Table 2). In other words, sleep quality was positively related to positive affect, which was in turn positively related to learning goal achievement. The ratio of the indirect effect to the total effect was 26% for positive affect; that is, 26% of the effect of average sleep quality on learning goal achievement was mediated by positive affect. However, even when the mediator positive affect was included in the analysis, the relation between sleep quality and learning goal achievement remained significant, implying that additional factors also influence the relation between sleep quality and learning goal achievement. Negative affect, in contrast, did not significantly mediate the relation between sleep quality and learning goal achievement.

The relation between average physical activity and average learning goal achievement was mediated by positive affect (see Table 2). In other words, physical activity was positively related to positive affect, which in turn predicted learning goal achievement. Positive affect mediated 88% of the total effect between average physical activity and learning goal achievement. Negative affect did not mediate the relation between physical activity and learning goal achievement. Because of the gender differences in negative affect, all mediation models including negative affect were also tested excluding male participants ($n = 8$), leaving a sample of $n = 64$. Coefficients derived from these models were comparable with those based on the full sample ($N = 72$). We did not test separate models for male participants because too few men were included in the sample ($n = 8$), precluding reliable estimates from multilevel structural equation models.

Hypothesis 1c: Association between learning goal achievement and examination success. Learning goal achievement positively predicted examination success. For every 1-point increase in average learning goal achievement over the examination period, the odds of passing all six examinations increased by three and a half (OR = 3.54, 95% CI: 1.42–8.81, $p = .006$).

Day-to-day level (within-person level)

Hypothesis 2a: Association of day-to-day sleep quality and physical activity with daily learning goal achievement (total effects). As shown in Table 3, on days with higher sleep quality, participants reported better learning goal achievement ($c = 0.76$, $SE = 0.33$, $p = .021$). However, day-to-day physical activity was not significantly associated with learning goal achievement ($c = -0.05$, $SE = 0.03$, $p = .116$).

Hypothesis 2b: Daily positive and negative affect as mediators (indirect and direct effects). When the two mediators, positive and negative affect, were included in separate models for each mediator, both mediated the within-person relation between sleep quality and learning goal achievement (see Table 3). Thus, on days with higher sleep quality, participants reported increased positive and decreased negative affect, which was in turn linked to better learning goal achievement. Forty-one percent of the effect of sleep quality on learning goal achievement was mediated by positive affect; 52% by negative affect. Note that the corresponding direct effects were no longer significant when either mediator was included in the analyses, suggesting full mediation.

Positive and negative affect both mediated the within-person relation between physical activity and learning goal achievement (see Table 3). Thus, higher physical activity was associated with higher positive and lower negative affect. In turn, positive affect

Table 3. Direct, total, and mediated effects of sleep quality and physical activity on learning goal achievement via positive and negative affect on a within-person level.

Predictor	Sleep quality Positive affect		Sleep quality Negative affect		Physical activity Positive affect		Physical activity Negative affect	
Mediator								
	B (*SE*)	*p*	*B* (*SE*)	*p*	*B* (*SE*)	*p*	*B* (*SE*)	*p*
a	1.90 (0.57)	.001	−0.85 (0.17)	<.001	0.17 (0.04)	<.001	−0.05 (0.01)	.001
b	0.16 (0.03)	<.001	−0.46 (0.07)	<.001	0.17 (0.03)	<.001	−0.48 (0.07)	<.001
ab (indirect effect)	0.31 (0.09)	.001	0.39 (0.08)	<.001	0.03 (0.01)	<.001	0.02 (0.01)	.001
Mediated proportion (%)	41%		52%		27%		23%	
c (total effect)	0.76 (0.33)	.021	0.76 (0.33)	.021	−0.05 (0.03)	.116	−0.05 (0.03)	.117
c′ (direct effect)	0.45 (0.32)	.160	0.36 (0.32)	.260	−0.08 (0.03)	.010	−0.07 (0.03)	.015

Note. Ratios are based on absolute values of direct and indirect effects, e.g. positive affect mediated 41% of the total effect between sleep quality and learning goal achievement. *a* = path from predictor to mediator; *b* = path from mediator to outcome;
B = unstandardized regression coefficient; *c* = *ab* (indirect effect) + *c′* (direct effect); *c′* = path from predictor to outcome after controlling for the mediator; *SE* = standard error.
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was related to better learning goal achievement; negative affect to poorer learning goal achievement. Although, as reported above, the association between physical activity and learning goal achievement (total effect) was not significant, the association between physical activity and learning goal achievement was significantly negative when positive and negative affect were controlled (direct effect). The combination of these *negative* direct effects (physical activity on learning goal achievement controlled for positive or negative affect) and *positive* indirect effects (physical activity on affect; affect on learning goal achievement) suggests inconsistent mediation [58]. Because direct and indirect effects were of fairly similar magnitudes and opposite signs, they cancelled each other out, resulting in a nonsignificant total effect [59]. In cases of inconsistent mediation, Alwin and Hauser [60] suggested to use absolute values of the direct and indirect effects to calculate the ratio of the indirect effect to the total effect. Following this approach, we found that positive affect mediated 27%, and negative affect 23% of the total effect between physical activity and learning goal achievement.

Discussion

This prospective longitudinal study examined how health behaviors were associated with academic performance during a stressful examination period, and tested whether affect underlies this relation. To our knowledge, this is one of the first studies to combine research on health behaviors, affect, and academic performance, and to consider the respective day-to-day dynamics over a period of time. The study has two main sets of findings: First, overall sleep quality predicted learning goal achievement, whereas overall physical activity was not related to learning goal achievement. Positive affect mediated the relation between both health behaviors and learning goal achievement. Negative affect, in contrast, did not mediate the relation between any of the two health behaviors and learning goal achievement. Importantly, overall learning goal achievement was a strong positive predictor of examination success. Second, in terms of day-to-day dynamics, on days on which participants reported higher sleep quality, they also reported better learning goal achievement. However, there was no significant relation between day-to-day physical activity and learning goal achievement. Day-to-day positive and negative affect both mediated the association between day-to-day sleep quality and learning goal achievement as well as day-to-day physical activity and learning goal achievement.

Sleep (not physical activity) predicts better learning goal achievement

In accordance with our hypothesis, students with higher overall sleep quality reported better overall learning goal achievement. This finding is in line with previous research on the between-person level indicating that better sleep quality is associated with better academic performance and grades in adolescents and young adults [4,6,7]. Importantly, the present study also replicated these findings on a day-to-day level: On days with better sleep quality, participants also reported better learning goal achievement, indicating that they might have experienced immediate improvement in their learning goal achievement. These results imply that high sleep quality in general as well as just one night of better sleep during a stressful examination period might help young adults to better achieve their learning goals.

Concerning average physical activity over the 32-day period, our results showed no association between physical activity and learning goal achievement. This result differs from previous research conceptualizing habitual physical activity as a trait, which showed that more physically active adolescents have better grades [9,10] and better academic performance [11]. Also, in contrast to our hypothesis, our results found no significant relation between day-to-day physical activity and learning goal achievement. One potential explanation for the missing association between physical activity and learning goal achievement in the present study might be that the assessment took place during the stressful examination period, in which time spent being physically active was not available for studying, which may thus have impeded learning goal achievement. Most previous studies were of cross-sectional design conducted during non-stressful periods [9]. Moreover, other studies on the between-person level have concentrated on the relation between physical activity and either cognitive performance [5], grades [9,10], or overall academic performance [11], whereas this study focused on learning goal achievement, which is more of a motivational variable. Overall, our results suggest that physical activity in general as well as on the day-to-day level seems to have no impact on learning goal achievement during an intensive preparation and examination period.

Affect as a mechanism underlying the relation between health behaviors and learning goal achievement

Average positive affect mediated the association between sleep quality and learning goal achievement, supporting our hypothesis. This finding extends previous research on the between-person level that has shown a positive relation between sleep quality and positive affect [30] and demonstrated that positive affect is related to better goal achievement and more favorable progress judgments [23]. However, to our knowledge, no previous research has tested the relation between sleep quality, affect, and learning goal achievement in a single model. Contrary to our hypothesis and previous research, negative affect did not mediate the effect of average sleep quality on learning goal achievement. Interestingly, on the day-to-day level, the association between sleep quality and learning goal achievement was mediated by both positive and negative affect, as predicted. This suggests that the overall negative affect experienced over the study period did not underlie the relation between sleep quality and learning goal achievement. Yet considering the day-to-day dynamics, on days with poor sleep quality, negative affect seems to be one of the mechanisms underlying the relation between sleep quality and learning goal achievement. Previous longitudinal studies have only tested parts of our model. For example, one study showed a positive relation between sleep quality and positive affect [31]. Another found positive affect to predict higher learning goals [22]. It seems plausible that current affect is used as input at the moment of judgments as suggested by the mood-as-information model [24]. For example, when participants in the current study were asked whether they had achieved today's learning goal, they may have consulted their momentary affect to judge the day's learning goal achievement. Positive affect would be indicative of high learning goal achievement, negative affect of low learning goal achievement. Mood is a particularly valuable source of information in the absence of regular formal performance feedback, as is the case during examination preparation periods, when students have to evaluate their learning outcomes and motivate themselves. This study is one of the first to suggest experienced affect as a mechanism potentially underlying the relation between day-to-day sleep quality and learning goal achievement, and its findings underline the importance of considering affect when investigating university students' health- and learning-related behaviors.

Concerning the relation between physical activity, positive affect, and learning goal achievement, we found that overall positive affect mediated the relation between overall physical

activity and learning goal achievement. In contrast, negative affect was not an underlying mechanism. Similar to sleep quality, negative affect over the stressful study period did not seem to play a role in the relation of physical activity and learning goal achievement. Day-to-day higher physical activity was indirectly linked with better learning goal achievement through increased positive and decreased negative affect. In other words, the affective benefits of engaging in physical activity during a stressful examination period, which is positively related to learning goal achievement, do not outweigh the reduced learning goal achievement associated with physical activity (controlled for positive or negative affect). Our results thus suggest that being physically active or not during the preparation and examination phase seem to have comparable immediate benefits and costs. These divergent findings for the between- and within-person level emphasize the importance of understanding day-to-day dynamics in addition to average values, and help disentangle short- and long-term effects of physical activity on academic performance.

Learning goal achievement predicts examination success

Importantly, learning goal achievement emerged as a strong predictor of passing all six examinations. These findings underline once again the importance of understanding behaviors that enhance learning goal achievement, such as sleep and physical activity.

Limitations

The following limitations of the present study should be noted. First, all data were assessed by means of online self-report questionnaires, including examination grades. The sample included in this study represents about half of all first-year psychology students at the University of Basel in the respective academic year. Importantly, the grades of our sample do not differ from the grades of all psychology students in that academic year. Additionally, participation in the current study was voluntary and anonymous; compensation for study participation was independent of examination outcome. While this is no proof of accuracy of the reported data, it is nevertheless a good indicator that participants did report their actual grades. Assessing grades from the official institution of the university (and thus not providing full anonymity to the students) might have compromised the accuracy of participants' study responses and thus the study goals. Future research should also obtain data on physical activity and sleep quality from additional, behavioral measurement sources such as accelerometry. However, previous studies have shown that behavioral assessments and subjective ratings of physical activity are significantly related [52,61].

Second, causal relations or disentangling the chronological order in which behaviors might have influenced each other cannot be inferred from the findings due to the observational study design. Importantly though, the directions of the hypotheses formulated were based on theoretical considerations and previous research. Third, due to the prospective nature of the study, 12% of the sample dropped out. This is a low dropout rate. However, to evaluate whether the study sample differs in academic performance of all first-year psychology students at the University of Basel, we compared our sample's examination pass rate with that of all first-year psychology students at the University of Basel during the academic year in which the study took place and found no difference in their grades. Fourth, while the naturalistic design of this study over a stressful examination period is an important strength, it is also a limitation in that it does not allow the results to be generalized to other periods of the university year. Moreover, the study population is limited to psychology students of the University of Basel, meaning that the results cannot necessarily be generalized to students of other departments or universities.

Furthermore, mental disorders and stress have been shown to be related to health behaviors and experienced affect [26,62]. While in the present study population only three students reported clinically relevant symptoms on the Beck Depression Inventory [63], other mental disorders were not assessed and might have affected the results. However, results of the analyses disregarding the three participants reporting clinically relevant symptoms on the Beck Depression Inventory were comparable to those including the full sample. Finally, in addition to sleep and physical activity, future research should also include day-to-day dynamics of other health behaviors, which might be relevant to affect or academic performance, such as eating behavior or alcohol consumption [64,65].

Conclusion

This study shed light on how two health behaviors—sleep quality and physical activity—are associated with affect and academic performance during a stressful examination period and highlighted the potential of these behaviors to promote young adults' academic performance. Notably, sleep quality was a stronger predictor of learning goal achievement than was physical activity on average but also on a day-to-day level. The findings extend the existing body of literature by integrating research on health behaviors, affect, and academic performance during a stressful examination period. Additionally, the results emphasize the importance of understanding within-person variability in sleep, physical activity, affect, and learning goal achievement in daily life. Designs such as that used in the present study make it possible to disentangle short- and long-term effects. For example, the present results showed that negative affect experienced over the study period did not underlie the relation between both health behaviors and learning goal achievement, however, on a daily measurement level, negative affect did mediate the relation between both sleep quality and physical activity with learning goal achievement. These findings provide important insights into what effects to expect, for example, in the process of a prevention or intervention program.

The within-person variability of health behaviors, learning goal achievement, and their underlying mechanisms is an important area for future research. This study is a first step toward a better understanding of the role of health behaviors for affect experience and academic performance during a demanding examination period at university. The findings can provide a basis for potential prevention and intervention programs that might allow more young adults to complete their first year at university in good physical and mental health as well as achieving their academic goals.

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Author Contributions

Conceived and designed the experiments: JM RL. Performed the experiments: JM. Analyzed the data: JM LF AHM. Contributed reagents/materials/analysis tools: JM AHM. Wrote the paper: LF RL AHM JM.

References

1. Organisation for Economic Cooperation and Development (OECD) (2010) Highlights from education at a glance 2010. Paris: Author. 22 p.
2. Bundesamt für Statistik [Federal agency for statistics] (2012) Studiendauer (retrospektiv) nach Hochschultyp und Studienstufe, 2007–2011 [Study period (retrospective) concerning type of tertiary education and academic level]. Neuchâtel, Switzerland: Author.
3. Organisation for Economic Cooperation and Development (OECD) (2012) Education at a glance 2012: Highlights. Paris: Author. 221 p.
4. Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bogels SM (2010) The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. Sleep Med Rev 14: 179–189.
5. Lambourne K, Tomporowski P (2010) The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. Brain Res 1341: 12–24.
6. Curcio G, Ferrara M, De Gennaro L (2006) Sleep loss, learning capacity and academic performance. Sleep Med Rev 10: 323–337.
7. Ahrberg K, Dresler M, Niedermaier S, Steiger A, Genzel L (2012) The interaction between sleep quality and academic performance. J Psychiatr Res 46: 1618–1622.
8. Field T, Diego M, Sanders CE (2001) Exercise is positively related to adolescents' relationships and academics. Adolescence 36: 105–110.
9. Hillman CH, Erickson KI, Kramer AF (2008) Be smart, exercise your heart: Exercise effects on brain and cognition. Nat Rev Neurosci 9: 58–65.
10. Kristjansson AL, Sigfusdottir ID, Allegrante JP (2010) Health behavior and academic achievement among adolescents: The relative contribution of dietary habits, physical activity, body mass index, and self-esteem. Health Educ Behav 37: 51–64.
11. Fedewa AL, Ahn S (2011) The effects of physical activity and physical fitness on children's achievement and cognitive outcomes: a meta-analysis. Res Q Exerc Sport 82: 521–535.
12. Kantomaa MT, Tammelin TH, Demakakos P, Ebeling HE, Taanila AM (2010) Physical activity, emotional and behavioural problems, maternal education and self-reported educational performance of adolescents. Health Educ Res 25: 368–379.
13. Kramer AF (1999) Ageing, fitness and neurocognitive function. Nature 402: 750–750.
14. Colcombe SJ, Kramer AF, Erickson KI, Scalf P, McAuley E, et al. (2004) Cardiovascular fitness, cortical plasticity, and aging. Proc Natl Acad Sci USA 101: 3316–3321.
15. MacIntosh BJ, Crane DE, Sage MD, Rajab AS, Donahue MJ, et al. (2014) Impact of a single bout of aerobic exercise on regional brain perfusion and activation responses in healthy young adults. Plos One 9: e85163.
16. Colcombe SJ, Erickson KI, Scalf PE, Kim JS, Prakash R, et al. (2006) Aerobic exercise training increases brain volume in aging humans. J Gerontol A Biol Sci Med Sci 61: 1166–1170.
17. Jones K, Harrison Y (2001) Frontal lobe function, sleep loss and fragmented sleep. Sleep Med Rev 5: 463–475.
18. Lyubomirsky S, King L, Diener E (2005) The benefits of frequent positive affect: Does happiness lead to success? Psychol Bull 131: 803–855.
19. Robbins SB, Oh IS, Le H, Button C (2009) Intervention effects on college performance and retention as mediated by motivational, emotional, and social control factors: Integrated meta-analytic path analyses. J Appl Psychol 94: 1163–1184.
20. Mega C, Ronconi L, De Beni R (2013) What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. J Educ Psychol 106: 121–131.
21. Daniels LM, Stupnisky RH, Pekrun R, Haynes TL, Perry RP, et al. (2009) A longitudinal analysis of achievement goals: From affective antecedents to emotional effects and achievement outcomes. J Educ Psychol 101: 948–963.
22. Richard EM, Diefendorff JM (2011) Self-regulation during a single performance episode: Mood-as-information in the absence of formal feedback. Organ Behav Hum Decis Process 115: 99–110.
23. Seo MG, Barrett LF, Bartunek JM (2004) The role of affective experience in work motivation. Acad Manage Rev 29: 423–439.
24. Schwarz N, Clore GL (2003) Mood as information: 20 years later. Psychol Inq 14: 296–303.
25. Miner AG, Glomb TM (2010) State mood, task performance, and behavior at work: A within-persons approach. Organ Behav Hum Decis Process 112: 43–57.
26. Baglioni C, Spiegelhalder K, Lombardo C, Riemann D (2010) Sleep and emotions: A focus on insomnia. Sleep Med Rev 14: 227–238.
27. Pilcher JJ, Huffcutt AI (1996) Effects of sleep deprivation on performance: A meta-analysis. Sleep 19: 318–326.
28. Walker MP (2009) The role of sleep in cognition and emotion. Ann N Y Acad Sci 1156: 168–197.
29. Franzen PL, Siegle GJ, Buysse DJ (2008) Relationships between affect, vigilance, and sleepiness following sleep deprivation. J Sleep Res 17: 34–41.
30. Bower B, Bylsma LM, Morris BH, Rottenberg J (2010) Poor reported sleep quality predicts low positive affect in daily life among healthy and mood-disordered persons. J Sleep Res 19: 323–332.
31. Sonnentag S, Binnewies C, Mojza EJ (2008) "Did you have a nice evening?" A day-level study on recovery experiences, sleep and affect. J Appl Psychol 93: 674–683.
32. Totterdell P, Reynolds S, Parkinson B, Briner RB (1994) Associations of sleep with everyday mood, minor symptoms and social interaction experience. Sleep 17: 466–475.
33. Hogan CL, Mata J, Carstensen LL (2013) Exercise holds immediate benefits for affect and cognition in younger and older adults. Psychol Aging 28: 587–594.
34. Mata J, Thompson RJ, Jaeggi SM, Buschkuehl M, Jonides J, et al. (2012) Walk on the bright side: Physical activity and affect in major depressive disorder. J Abnorm Psychol 121: 297–308.
35. Reed J, Buck S (2009) The effect of regular aerobic exercise on positive-activated affect: A meta-analysis. Psychol Sport Exerc 10: 581–594.
36. Reed J, Ones DS (2006) The effect of acute aerobic exercise on positive activated affect: A meta-analysis. Psychol Sport Exerc 7: 477–514.
37. Paluska SA, Schwenk TL (2000) Physical activity and mental health - Current concepts. Sports Med 29: 167–180.
38. Jacobi F, Wittchen HU, Holting C, Hofler M, Pfister H, et al. (2004) Prevalence, co-morbidity and correlates of mental disorders in the general population: Results from the German Health Interview and Examination Survey (GHS). Psychol Med 34: 597–611.
39. Kessler RC, Berglund P, Demler O, Jin R, Walters EE (2005) Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. Arch Gen Psychiatry 62: 593–602.
40. Dyson R, Renk K (2006) Freshmen adaptation to university life: Depressive symptoms, stress, and coping. J Clin Psychol 62: 1231–1244.
41. Furnham A, Chamorro-Premuzic T, McDougall F (2002) Personality, cognitive ability, and beliefs about intelligence as predictors of academic performance. Learn Individ Differ 14: 47–64.
42. Neisser U, Boodoo G, Bouchard TJ, Boykin AW, Brody N, et al. (1996) Intelligence: Knowns and unknowns. Am Psychol 51: 77–101.
43. Strenze T (2007) Intelligence and socioeconomic success: A meta-analytic review of longitudinal research. Intelligence 35: 401–426.
44. Robbins SB, Lauver K, Le H, Davis D, Langley R, et al. (2004) Do psychosocial and study skill factors predict college outcomes? A meta-analysis. Psychol Bull 130: 261–288.
45. Richardson M, Abraham C, Bond R (2012) Psychological correlates of university students' academic performance: A systematic review and meta-analysis. Psychol Bull 138: 353–387.
46. Morisano D, Hirsh JB, Peterson JB, Pihl RO, Shore BM (2010) Setting, elaborating, and reflecting on personal goals improves academic performance. J Appl Psychol 95: 255–264.
47. Kuhl J (1994) Motivation and volition. In: D'Ydewalle G, Eelen P, Bertelson P, editors. International perspectives on psychological science: The state of the art. Hillsdale, NJ: Lawrence Erlbaum. pp. 311–340.
48. Zheng JL, Saunders KP, Shelley MC, Whalen DF (2002) Predictors of academic success for freshmen residence hall students. J Coll Stud Dev 43: 267–283.
49. Riemann D, Backhaus J (1996) Behandlung von Schlafstörungen [Treatment of sleep disorders]. Weinheim, Germany: Beltz Psychologie-Verlag-Union.
50. Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ (1989) The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res 28: 193–213.
51. Godin G, Shephard RJ (1985) A simple method to assess exercise behavior in the community. Can J Appl Sport Sci 10: 141–146.
52. Jacobs DR Jr, Ainsworth BE, Hartman TJ, Leon AS (1993) A simultaneous evaluation of 10 commonly used physical activity questionnaires. Med Sci Sports Exerc 25: 81–91.
53. Roecke C (2006) Intraindivual variability in positive and negative affect: Age-related and individual differences in magnitude and coupling with cognitive performance. Doctoral Thesis, Freie Universität Berlin, Germany. Available: http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002464?lang=en. Accessed 23 September 2013.
54. Watson D, Clark LA, Tellegen A (1988) Development and validation of brief measures of positive and negative affect: The PANAS scales. J Pers Soc Psychol 54: 1063–1070.
55. Preacher KJ, Zyphur MJ, Zhang Z (2010) A general multilevel SEM framework for assessing multilevel mediation. Psychol Methods 15: 209–233.
56. Raudenbush SW, Bryk AS (2002) Hierarchical linear models: Applications and data analysis methods. Thousand Oaks, CA: Sage Publications. 485 p.
57. Babyak MA (2004) What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models. Psychosom Med 66: 411–421.
58. MacKinnon DP, Fairchild AJ, Fritz MS (2007) Mediation analysis. Annu Rev Psychol 58: 593–614.
59. MacKinnon DP, Krull JL, Lockwood CM (2000) Equivalence of the mediation, confounding and suppression effect. Prev Sci 1: 173–181.
60. Alwin DF, Hauser RM (1975) The decomposition of effects in path analysis. Am Sociol Rev 40: 37–47.
61. Bussmann JBJ, Ebner-Priemer UW, Fahrenberg J (2009) Ambulatory activity monitoring progress in measurement of activity, posture, and specific motion patterns in daily life. Eur Psychol 14: 142–152.
62. Brown GW, Harris TO (1989) Life events and illness. New York: Guilford. 49 p.
63. Beck AT, Ward CH, Mendelson M, Mock J, Erbaugh J (1961) An inventory for measuring depression. Arch Gen Psychiatry 4: 561–571.

64. Gomez-Pinilla F (2008) Brain foods: The effects of nutrients on brain function. NatRev Neurosci 9: 568–578.

65. Perkins WH (2002) Surveying the damage: A review of research on consequences of alcohol misuse in college populations. J Stud Alcohol Drugs Suppl 14: 91–100.

Appendix B

Day-to-Day Variations in Health Behaviors and Daily Functioning:

Two Intensive Longitudinal Studies

Flueckiger, L., Lieb, R., Meyer, A., Witthauer, C., & Mata, J.

(under review in *Health Psychology*)

Day-to-Day Variations in Health Behaviors and Daily Functioning: Two Intensive Longitudinal Studies

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Abstract

Objective: Health behaviors tend to show high intraindividual variability over time. However, most previous research has provided only a "snapshot" of people's behavior and not captured this natural daily variability. Two intensive longitudinal studies examined variability in university students' health behaviors over one academic year and its associations with other aspects of their daily life, namely affect and academic performance. Can a single day of increased physical activity, snacking, or improved sleep have beneficial effects? ***Methods:*** In two intensive longitudinal studies with up to 65 assessments over an academic year, students (Study 1: $N = 292$; Study 2: $N = 304$) reported sleep quality, physical activity, snacking, positive and negative affect, and learning goal achievement. ***Results:*** Multilevel structural equation models showed that, on days on which participants reported better sleep quality or more physical activity than usual, they also reported increased positive affect, decreased negative affect, and better learning goal achievement. Higher day-to-day snacking was associated with increased positive affect. Increased day-to-day sleep quality and physical activity were both indirectly associated with better learning goal achievement through changes in positive and negative affect; results for snacking were mixed. Importantly, day-to-day sleep quality was a stronger predictor of affect and learning goal achievement than was either day-to-day physical activity or snacking. ***Conclusions:*** A day of more physical activity or a night of better sleep than usual is associated with a day of improved affect and academic performance. These findings have important implications for low-threshold interventions targeting the improvement of daily functioning.

Keywords: sleep quality, physical activity, snacking, affect, academic performance, multilevel structural equation model

Introduction

It is well established that young adults who follow a healthy lifestyle nurture their physical health (World Health Organization [WHO], 2002). Less is known about the role of health behaviors for other crucial aspects of young adults' daily functioning, such as affect and academic performance. To date, the literature has focused primarily on cross-sectional or experimental data. These studies have reliably shown that health behaviors such as sleep, physical activity, and eating (Schoenborn, 1986) are associated with increased positive affect (Walsh, 2011) and better academic performance (Burkhalter & Hillman, 2011; Lucke & Partridge, 2013). Importantly, however, cross-sectional and experimental studies can provide only a "snapshot" of people's behavior and serve as a basis for interindividual comparisons. Yet health behaviors tend to show high intraindividual variability over time, which can be dissimilar to between-person associations (Molenaar, 2004). The aim of the two longitudinal observation studies presented here was to investigate, over the course of an academic year, how naturally occurring day-to-day variations in individual students' sleep, physical activity, and eating are associated with affect and academic performance—two essential aspects of daily functioning in young adults.

Health Behaviors and Daily Functioning

One line of previous research has examined how sleep quality, physical activity, and snacking are associated with positive and negative affect. A few studies showed that day-to-day sleep quality was associated with increased positive affect (Flueckiger, Lieb, Meyer, & Mata, 2014; Sonnentag, Binnewies, & Mojza, 2008). Bouts of physical activity have consistently been linked to increased positive affect in experimental studies (Hogan, Mata, & Carstensen, 2013; for a meta-analysis, see Reed & Ones, 2006). Likewise, increased physical activity has been associated with increased positive affect in longitudinal studies over one day to six weeks (for review, see Kanning, Ebner-Priemer, & Schlicht, 2013). Evidence concerning snacking is unclear: Some studies suggested increased positive affect (Benton,

Slater, & Donohoe, 2001; Desmet & Schifferstein, 2008; Smith & Wilds, 2009) and decreased negative affect after snacking (Hartmann, Rief, & Hilbert, 2012), whereas other studies showed that snacking was linked with reduced positive affect (Hormes & Rozin, 2011) and guilt (Macht & Dettmer, 2006; Steenhuis, 2009). Importantly, the amount of snacking has substantially increased in recent decades; it now accounts for a large part of the total energy intake in young adults, and is thus one of the most important descriptors of eating behavior (Zizza, Siega-Riz, & Popkin, 2001).

Another line of research, mainly cross-sectional, has examined the associations between health behaviors and academic performance and shown, for example, that higher sleep quality is associated with better academic performance (Curcio, Ferrara, & De Gennaro, 2006). Likewise, an intensive longitudinal study found that first-year university students reported better academic performance during a stressful examination period after getting a better night's sleep (Flueckiger et al., 2014). Higher levels and single bouts of physical activity have consistently been associated with better grades and better cognitive performance, respectively, in meta-analyses and reviews based on cross-sectional and experimental studies (Chang, Labban, Gapin, & Etnier, 2012; Hillman, Erickson, & Kramer, 2008). A review of longitudinal studies has revealed similar results (Busch et al., 2014). However, it is important to note that most of these assessments were conducted at intervals of one or two years and therefore did not capture daily variations in health behaviors. In contrast, day-to-day physical activity did not prove to be associated with academic performance during a stressful four-week examination period (Flueckiger et al., 2014). Concerning snacking, Miller and colleagues (2013) have suggested that increased snacking and eating frequency seem to be more beneficial for cognitive performance than lower eating frequency.

Affect as a Potential Mechanism Underlying the Association Between Health Behaviors and Academic Performance

Various physiological mechanisms have been proposed to underlie the association between health behaviors and cognitive performance, such as increased cerebral blood flow and cortical volume through enhanced physical activity (Marmeleira, 2013). Less is known about potential underlying psychological mechanisms. One candidate mechanism might be affect—that is, health behaviors might influence academic performance through changes in affect (Flueckiger et al., 2014; Wong et al., 2013).

Previous research indicates that positive affect is associated with successful academic performance (Lyubomirsky, King, & Diener, 2005). The mood-as-information theory assumes that current affect serves as a source of information for judgments (Schwarz & Clore, 2003). When students study for a major exam over several weeks, immediate feedback is absent and they might use current affect as input for setting learning goals (Richard & Diefendorff, 2011) and for learning goal achievement (Flueckiger et al., 2014). Importantly, daily goal setting and learning goal achievement have been shown to predict long-term achievement such as better grades (Flueckiger et al., 2014; Morisano, Hirsh, Peterson, Pihl, & Shore, 2010), which are still the most widespread measure of academic performance in tertiary education (Robbins et al., 2004). These findings underline the importance of understanding how predictors of daily behaviors are associated with long-term achievement.

The Present Studies

The two intensive longitudinal studies presented here aim at understanding how daily variations in sleep quality, physical activity, and snacking are associated with important indicators of daily functioning, namely affect and academic performance, over the first year at university. The studies build on a previous study on students' health behaviors and daily functioning (Flueckiger et al., 2014) by extending the observation period from a stressful four-week examination period to an entire academic year with more assessment points as well as larger and more diverse study populations. Further, we consider additional health behaviors and obtain behavioral measures to complement self-report data. With two independent

samples, the present studies allow us to determine whether findings can be replicated. The design allows us to compare the effects of different levels of health behavior within the same person, without potential confounders that compromise between-person studies (e.g., gender, socioeconomic status). Importantly, this is the first research to compare the relative influence of the three health behaviors—sleep quality, physical activity, and snacking—on daily functioning in a longitudinal setting. Drawing on the literature described above, we propose the following hypotheses:

(1a) On days on which students report higher sleep quality, more physical activity, or more snacking than usual (i.e., higher than their personal average), they also report increased positive affect.

Since some evidence suggested increased positive affect after snacking and some showed facets of negative affect after snacking, a competing hypothesis is proposed:

On days on which students report more snacking than usual, they report decreased positive affect.

(1b) On days on which students report higher sleep quality, more physical activity, or more snacking than usual, they also report decreased negative affect.

Similar to positive affect, a competing hypothesis is suggested for negative affect:

On days on which students report more snacking than usual, they report increased negative affect.

(2) On days on which students report higher sleep quality, more physical activity, or more snacking than usual, they also report better learning goal achievement.

(3a) Daily positive affect mediates the association of day-to-day sleep quality, physical activity, and snacking, on the one hand, with learning goal achievement, on the other (e.g., on days with higher sleep quality, students experience higher positive affect, which in turn predicts better learning goal achievement).

(3b) Daily negative affect mediates the association of day-to-day sleep quality, physical activity, and snacking with learning goal achievement.

In addition, we explore whether and how the three health behaviors sleep quality, physical activity, and snacking differ in their strength of associations with affect and learning goal achievement. In the following, we first report the methods of the two studies separately before presenting their results together.

Method

Study 1

Design and Procedure

Data were obtained from an intensive longitudinal survey during the first year at university from November 2011 to July 2012. Participants were recruited through announcements made during introductory lectures that are obligatory for first-year students majoring in psychology, law, or natural sciences at the University of [name omitted to maintain anonymity]. Interested students provided their e-mail address and received an e-mail with a link to an online entry survey. The first page of the entry survey contained detailed information about the study; participants had to give informed consent before they could continue. After admission to the survey, they were invited to participate in 61 short online surveys, each taking on average 5.30 minutes (SD = 1.38) to complete. The first 28 survey invitations were sent out every six days. This six-day interval during the first half of the academic year was chosen to ensure that the study covered all weekdays about equally often, to keep participant burden acceptable, and to minimize study drop-out. The other 33 survey invitations were sent out on consecutive days during the end-of-year examination period. These examinations are obligatory for all first-year students in the recruited majors. Finally, participants completed an online exit survey.

In each survey, participants were asked to enter their personal code (made up of letters from their mother's and their own first name and their mother's birthday). This code was used

to link individual participants' data. Participants were never asked to give any information that would allow them to be identified; personal codes could not be linked to e-mail addresses.

Participants were additionally invited to a 3-hour experimental session, in which they took part in the Trier Social Stress Test for Groups, a validated psychosocial stress test (von Dawans, Kirschbaum, & Heinrichs, 2011). As the aim of this article is to elucidate the associations between health behaviors, affect, and academic performance, the experimental data are not considered in the present analyses.

All participants were offered financial compensation for their participation. Psychology students could choose between financial compensation, equivalent course credits in psychology, or a mix of both. The study was approved by the local ethics committee, [name omitted to maintain anonymity], reference number EK: 48/11.

Participants

A total of 323 students participated in the daily online surveys. Of these, 31 (10%) were excluded from the analyses because they responded to only three or fewer online surveys, not allowing statistical analyses on cubic associations. The final sample was thus N = 292 (see Table 1 for sample characteristics and intraclass correlations). The 292 participants provided a total of 11,114 responses over the 61 surveys; on average, each participant completed M = 38 surveys (SD = 18; range: 4–61), which represents a compliance rate of 62% (range: 7–100%).

Because within-person analyses focus on associations within the same person—in our case, comparing individual reports across the days of the study—we did not consider gender differences in the variables of interest: Gender as a time-invariant predictor has no impact on time-varying predictors.

First-year university students are a particularly suitable population for testing the hypotheses of the present article: First, they are exposed to the same stressors (here, end-of-

year examinations) at the same time—they are thus in a natural, but relatively controlled, setting. Second, most students are of comparable educational background and age; thus, they represent a relatively homogeneous population. Third, all university students have Internet access through the university; therefore, online assessment does not impose a selection bias.

Measures

Entry and Exit Questionnaire. *Sociodemographic information* was collected through the entry questionnaire (see Table 1).

Daily Questionnaire. *Sleep quality* was evaluated with the item from the German version of the Pittsburgh Sleep Quality Index (Riemann & Backhaus, 1996) which has been found to show the highest correlation with the final score of the full scale (single item–total correlation: $r = 0.83$) and construct validity discriminating good from bad sleepers (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Specifically, participants indicated their sleep quality during the previous night on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*).

Physical activity was assessed with the Godin Leisure-Time Exercise Questionnaire (Godin & Shephard, 1985), adapted to the daily online questionnaire format (see Mata et al., 2012). Participants were asked to report their physical activity during the last 24 hours in terms of the number of minutes engaged in mild (minimal effort; e.g., easy walking), moderate (not exhausting; e.g., fast walking), and strenuous exercise (heart beats rapidly; e.g., running). The daily minutes of mild, moderate, and strenuous physical activity were weighted by metabolic equivalents and summed to produce a total daily leisure activity score. High scores mirror high levels of physical activity (Godin & Shephard, 1985). The original Godin Leisure-Time questionnaire has been shown to have adequate concurrent validity with accelerometry (Jacobs, Ainsworth, Hartman, & Leon, 1993).

Snacking was defined as every snack outside main meals. Participants indicated the number of high-fat sweet snacks (e.g., chocolate, ice cream), high-fat savory snacks (e.g.,

chips, pizza), low-fat savory snacks (e.g., bread, pretzel), and other snacks, which were then summed up to a daily snacking score.

Positive and negative affect were obtained with the German version of the pleasantness scale (Roecke, 2006), a six-item instrument that has been found to lead to comparable results as the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988) in a nonclinical sample (Roecke, 2006). Participants rated the extent to which they had felt each of the following during the last 24 hours on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*): happy, content, cheerful, sad, downhearted, and frustrated. Internal consistency reliabilities were $\alpha = .94$ ($M = 14.54$, $SD = 4.18$) for positive affect and $\alpha = .85$ ($M = 7.00$, $SD = 3.96$) for negative affect, calculated across all 61 measurement occasions.

Learning goal achievement was obtained by asking participants whether they had achieved their self-set learning goals for the previous 24 hours on a 5-point Likert scale from 0 (*not at all*) to 4 (*completely*) (see Richard & Diefendorff, 2011). To determine the external validity of daily learning goal achievement, we related the students' average end-of-year examination grades reported in the exit questionnaire, to their average reported learning goal achievement over the entire academic year. It is important to note that these examination grades are the sole criterion determining whether or not a student can continue studying his/her major and is thus a key parameter for academic success in the first year at university. As examination grades were assessed only once, at the end of the academic year, this variable could only be analyzed on the between-person level. Importantly, of the 292 participants, 155 stated their examination grades. This subsample of 155 was used to assess external validity of daily learning goal achievement.

Note that in this article we often subsume affect and learning goal achievement and call these constructs daily functioning.

Statistical Analyses

As repeated measurement points were nested within participants, we used multilevel structural equation models to deal appropriately with varying time intervals and missing data (Preacher, Zyphur, & Zhang, 2010). Specifically, we applied a two-level model with measurements of health behaviors, affect, and learning goal achievement nested within participants. Multilevel structural equation models use person-mean centering by default. Thus, variables on the within-person level denote deviations from each individual's mean (e.g., days with high vs. low physical activity relative to the mean physical activity across all measurement days of a particular person).

Multilevel structural equation models simultaneously test the associations between all variables included in the model; here, all three predictors (sleep quality, physical activity, and snacking), one mediator (positive or negative affect), and one outcome variable (learning goal achievement; see Fig. 1). Importantly, the mediators are analyzed in two distinct models. Coefficients were standardized to compare the strength of associations of the three health behaviors with affect and learning goal achievement. To account for potential nonlinear trends of affect and learning goal achievement over time, we included temporal linear, quadratic, and cubic terms in the model. As physical activity, snacking, and negative affect were not normally distributed, we conducted logarithmic and square root transformations to approximate normal distributions. Regression analyses were conducted to analyze the relation between average learning goal achievement and average examination grades. MPlus (version 7.11) (Muthén & Muthén, 1998–2012) was used for multilevel structural equation models and R (R version 2.15.1) for the remaining analyses.

Study 2

Study 2 is an extension of Study 1 in two important ways: First, additionally to self-report, in Study 2 health behaviors were behaviorally measured by actigraph watches and snack intake in a controlled setting. Secondly, Study 2 consisted of four more assessment points and a slightly larger study population.

Design and Procedure

First-year students at the University of [name omitted to maintain anonymity] completed online surveys during October 2012 to July 2013. Participants were recruited through announcements made during lectures and flyers handed out and posted in several departments. Interested students either gave their e-mail address to the research team and received an e-mail with a link to an online entry survey or accessed the entry survey directly by following instructions provided in the flyers. After informed consent, participants were invited to 65 short online surveys, each taking on average 5.38 minutes (*SD* = 1.23) to complete. The first 35 online surveys were sent out every six days; the other 30 on consecutive days over a stressful end-of-year examination period. These examinations are obligatory for all first-year students in the recruited majors. Additionally, participants were invited to an experimental session, which included a stress test (results not reported here) and 10 minutes of exposure to various snacks, and a subsample of participants wore actigraph watches for one week.

Participants

A total of 337 first-year university students participated in Study 2. Of these, 33 (10%) were excluded because they responded to only three or fewer daily surveys, not allowing statistical analyses on cubic relations. The final sample was thus *N* = 304 (see Table 1 for sample characteristics and intraclass correlations). These participants provided a total of 11,904 responses over the 65 surveys; on average, each participant completed *M* = 39 surveys (*SD* = 19; range: 4–65), which represents a compliance rate of 60% (range: 6–100%). As in Study 1, gender differences were not analyzed due to the within-person design.

Measures

For those measures already described for Study 1, only reliability is reported in the following. The other measures are explained in detail.

Entry and Exit Questionnaire. *Sociodemographic information* was collected through the entry questionnaire (see Table 1).

Daily Questionnaire. *Sleep quality, physical activity, snacking*, *positive and negative affect* (positive affect: $\alpha = .92$, $M = 14.53$, $SD = 4.06$; negative affect $\alpha = .85$, $M = 6.59$, $SD = 3.83$, calculated for all 65 measurement occasions), and *learning goal achievement* were assessed with the same scales as in Study 1. Of the 304 participants, 233 reported their grades in the exit questionnaire. This subsample of 233 was used to assess the external validity of our daily measure of learning goal achievement.

Experimental Session. As in Study 1, participants were invited to take part in the Trier Social Stress Test for Groups (von Dawans et al., 2011), a validated psychosocial stress test ($N = 150$; results not reported here). Subsequently, they were offered a plate with four different snacks to assess the agreement between their self-reported snacking in the online survey (averaged over the 65 measurement occasions) and objectively measured snack intake. They were offered high-fat savory snacks (70 g chips), low-fat savory snacks (70 g pretzels), high-fat sweet snacks (70 g chocolate cookies), and low-fat sweet snacks (150 g grapes) (compare Chambers & Yeomans, 2011). The types of snacks were chosen to be eaten in the moment and make it inconvenient to take them away for later. Participants were invited to take 10 minutes to relax, read magazines, and eat as much as they liked (see Hartmann, Rief, & Hilbert, 2012); they were not told that their consumption would be monitored. Importantly, participants had been asked not to eat for 2 hours before undergoing the 3-hour Trier Social Stress Test, and they were not allowed to eat during the experimental session. We thus created a controlled situation in which all participants had not eaten for several hours. Snacks were weighed in grams using a calibrated scale before and after snack exposure, and the difference was calculated.

In addition, a subsample of the participants ($N = 55$) who participated in the experimental session wore an actigraph watch (Motionlogger Actigraph, Ambulatory

Monitoring, Arlington, NY) for 7 consecutive days to assess the agreement of self-reported sleep and physical activity with behaviorally measured sleep and physical activity. Only participants who wore the actigraph for at least 5 days were included in the analyses, leaving a final sample of $N = 42$. Participants wore the actigraph on the nondominant wrist for 24 hours a day, except when showering or swimming, and completed daily online diaries indicating their total sleep duration (hours and minutes of sleep; this may differ from the numbers of hours spent in bed), bedtimes, number of minutes of physical activity, and when the actigraph was off. Data were analyzed using Action4 (Ambulatory Monitoring), with recordings set for 1-minute epochs (Chen & Bassett, 2005). We applied zero-crossing mode for sleep duration and proportional integration mode for physical activity (Chen & Bassett, 2005). For physical activity, we included only waking hours in the analyses, defined as the moment from getting out of bed in the morning until the moment of getting into bed at night (see Weikert, Motl, Suh, McAuley, & Wynn, 2010).

Statistical Analyses

As our intention was to replicate the results of Study 1, we used the same multilevel mediation models (see Fig. 1). Correlation analyses were conducted to assess the agreement between self-reported snacking and behaviorally measured snack intake. As actigraph data were assessed over 7 days and measurement points were thus nested within participants, we used multilevel analyses to analyze the agreement of self-reported sleep duration and physical activity with behaviorally measured sleep duration and physical activity. Standardized coefficients are reported.

Results

Descriptive Statistics

Descriptive statistics and intraclass correlations for the Study 1 and Study 2 variables are presented in Table 1. The proportion of female participants in both studies was high. Participants in both studies reported rather high sleep quality and medium snacking. There

was a considerable variability in reported physical activity in both studies, but on average 13% less physical activity was reported in Study 1 than in Study 2. Participants also reported medium learning goal achievement and higher positive than negative affect in both studies.

Correlation analyses between self-reported snacking (average across the entire survey) and the behaviorally measured snack intake showed that participants who reported eating more high-fat sweet snacks also consumed more cookies in the experimental session, $r = .25$, $p = .002$. Similarly, participants who reported eating more high-fat savory snacks consumed more chips, $r = .31$, $p < .001$, and those who reported eating more low-fat savory snacks consumed more pretzels, $r = .28$, $p < .001$. Grape consumption was not analyzed because fruit and vegetable intake was not included in the daily self-reported snack intake score.

The actigraph analyses showed that self-reported sleep duration was associated with behaviorally measured sleep duration in the same night ($\beta = 0.75$, $SE = 0.04$, $p < .001$). Likewise, self-reported physical activity was associated with behaviorally measured physical activity ($\beta = 0.18$, $SE = 0.06$, $p = .003$).

Importantly, in both studies, participants with higher average learning goal achievement over the study period reported higher average end-of-year examination grades (Study 1: $\beta = 0.20$, $SE = 0.09$, $z = 2.15$, $p = .031$; Study 2: $\beta = 0.16$, $SE = 0.07$, $z = 2.37$, $p = .018$).

Associations Between Day-to-Day Health Behaviors and Daily Functioning

Results for the associations between day-to-day health behaviors and daily functioning are presented in Figure 1. In line with our hypotheses, both studies showed that, on days on which participants reported better sleep quality or more physical activity than usual (i.e., higher than their personal average), they also reported increased positive and decreased negative affect (effects controlled for the other predictors in the model). Only Study 1 showed a positive association between day-to-day snacking and positive affect.

Consistent with our hypotheses concerning academic performance, both studies showed that, on days on which participants reported higher sleep quality than usual, they also reported better learning goal achievement (total effects controlled for the other predictors). No association between day-to-day physical activity and learning goal achievement emerged in Study 1. In Study 2, in contrast, on days on which participants reported being more physically active than usual, they also reported better learning goal achievement. Neither study found evidence of an association between day-to-day snacking and learning goal achievement.

Day-to-Day Health Behaviors are Associated with Academic Performance via Affect

Positive and negative affect (which were included in separate models) both mediated the association between day-to-day sleep quality and learning goal achievement in both studies (see Table 2 and Fig. 1). Specifically, on days with better sleep quality, participants reported higher positive and lower negative affect. In turn, positive affect was associated with better learning goal achievement, and negative affect to poorer learning goal achievement. In Study 1, 42% and 39% of the effect of sleep quality on learning goal achievement was mediated by positive affect and negative affect, respectively (see Table 2 for Study 2). Note that, in contrast to Study 1, in Study 2 the direct effects were no longer significant when either mediator was entered.

In Study 1, there was an indirect effect of day-to-day physical activity on learning goal achievement through changes in both positive and negative affect.1 Thus, on days on which participants reported being more physically active than usual, they also reported higher

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1Note the distinction between the terms “mediated effect” and “indirect effect”. A mediated effect implies that the corresponding total effect was initially present. There is no such assumption for an indirect effect: It is possible to detect an indirect effect even when the total effect is not significant. In such cases, it is preferable to use the term “indirect effect” rather than “mediated effect” (Preacher & Hayes, 2004).

positive and lower negative affect, which were both in turn linked to better learning goal achievement on that day. In Study 2, positive and negative affect mediated the association between day-to-day physical activity and learning goal achievement.

In Study 1, day-to-day snacking had an indirect effect on learning goal achievement through changes in positive affect, but not in negative affect. Results of Study 2 did not show any indirect effects of either positive or negative affect on the association between day-to-day snacking and learning goal achievement.

Relative Influence of the Three Health Behaviors on Daily Functioning

Standardized estimates allowed the comparison of the relative influence of the three health behaviors on daily functioning. Both studies showed that sleep quality was a stronger predictor of affect and learning goal achievement than was either physical activity or snacking (see Fig. 1).

Discussion

The results of our two intensive longitudinal studies extend previous research in numerous important ways: (1) More than half of the naturally occurring variation in sleep quality, physical activity, and snacking was due to within-person variability (see intraclass correlation in Table 1). This finding emphasizes the importance of evaluating health behaviors within the same person rather than merely between persons. (2) On up to 65 days over the first year at university, day-to-day sleep quality and physical activity were associated with increased positive and decreased negative affect across both studies. Day-to-day snacking was associated with positive affect only in Study 1. Furthermore, day-to-day sleep quality, but not snacking, was associated with learning goal achievement in both studies. Day-to-day physical activity was associated with learning goal achievement only in Study 2. These findings are especially relevant because they show that even a single night of better sleep quality or a single day of more physical activity than usual were beneficial for affect and academic performance, two important aspects of daily functioning in young adults. (3)

Combining two lines of research by evaluating health behaviors, affect, and academic performance simultaneously showed that increased sleep quality and physical activity were both indirectly associated with better learning goal achievement through increased positive and decreased negative affect. Negative affect was not an underlying mechanism in the association between snacking and learning goal achievement; results for positive affect were mixed across the two studies. These findings enhance our understanding of potential mechanisms underlying the relation association health behaviors and academic performance. (4) Importantly, the results of both studies showed that sleep quality is the strongest predictor of affect and academic performance—stronger than physical activity or snacking. This finding can inform promotion and intervention programs targeting specific health behaviors. (5) Two independent studies yielded congruent findings on the association between three health behaviors, affect, and academic performance (exceptions: the association between physical activity and learning goal achievement, as well as between snacking and positive affect).

Association Between Day-to-Day Health Behaviors and Daily Functioning

With respect to affect, day-to-day sleep quality was associated with increased positive and decreased negative affect in both studies. This result replicates and extends previous longitudinal findings demonstrating that nights with better sleep quality were associated with increased positive and decreased negative affect (Flueckiger et al., 2014; Sonnentag et al., 2008). By the same token, day-to-day physical activity was associated with increased positive and decreased negative affect, consistent with previous research (Kanning et al., 2013). In Study 1, day-to-day snacking was associated with increased positive affect. This result was not replicated in Study 2. Importantly, snacking was not associated with negative affect in either study. Findings of previous research to date on snacking and affect are mixed: some studies found increased positive (Benton et al., 2001; Smith & Wilds, 2009) and decreased negative affect (Hartmann et al., 2012) after snacking, whereas others found facets of negative affect (Hormes & Rozin, 2011; Steenhuis, 2009) or no association (Hewlett, Smith, & Lucas,

2009). One possible reason for the mixed findings is that most previous research was based on experimental studies with controlled administration of snacks, whereas the present studies assessed snacking repeatedly in a real-world context over a time span of several months.

With respect to academic performance, on days on which students reported better sleep quality than usual, they also reported better learning goal achievement. This result corresponds with findings from previous longitudinal (Flueckiger et al., 2014) and cross-sectional research (Curcio et al., 2006). Daily variations in physical activity were associated with learning goal achievement in Study 2, but not in Study 1. The findings of Study 2 were thus consistent with our hypothesis and with previous meta-analyses and reviews showing better grades and cognitive performance in more physically active adolescents (Busch et al., 2014; Hillman et al., 2008). In a previous study, however, we found no association between day-to-day physical activity and learning goal achievement over a stressful 4-week examination period (Flueckiger et al., 2014). Potential explanations for these mixed results include the different time frames (e.g., 4 weeks versus an entire academic year). However, the time frames of Study 1 and Study 2 were comparable, making this explanation less likely. Therefore, further research is needed to clarify the association between physical activity and learning goal achievement in daily life. There was no association between day-to-day snacking and learning goal achievement. This finding is contrary to our hypothesis and the results of other experimental studies evaluating cognitive performance after snacking (Benton et al., 2001; Miller et al., 2013; Smith & Wilds, 2009). However, a previous cross-sectional self-report study did not find an association between cognitive performance in young adults and snacking habits either (Smith, 2011). These differences indicate that the assessment method and time frame used may affect the study of snacking. Note, however, that our snacking measure showed a substantial correlation with actual snacking in a controlled laboratory situation.

Affect as a Mechanism Underlying the Association Between Day-To-Day Health Behaviors and Academic Performance

As predicted, day-to-day sleep quality and physical activity were indirectly associated with learning goal achievement via both positive and negative affect in both studies. When students reported better sleep quality or more physical activity than usual, they experienced higher positive affect and lower negative affect, which was in turn associated with better learning goal achievement. These findings are in line with those of a previous four-week longitudinal study (Flueckiger et al., 2014). In contrast, day-to-day snacking was indirectly associated with better learning goal achievement through increased positive affect, but not negative affect. Importantly, most previous studies have analyzed only parts of our model. For example, nights with better sleep quality was found to be associated with increased positive subsequent affect (Sonnentag et al., 2008), more physical activity was found to be associated with increased positive affect (e.g., Wichers et al., 2012), and higher day-to-day positive affect was found to predict higher learning goals (Richard & Diefendorff, 2011). In accordance with the mood-as-information model (Schwarz & Clore, 2003), it seems plausible that students might have consulted their current affect when evaluating their day-to-day learning goal achievement. Especially in the absence of regular feedback, as is the case during long study periods at university, mood is a particularly valuable source of information. This finding emphasizes the importance of considering affect when investigating university students' health- and learning-related behaviors.

Sleep Quality as the Strongest Predictor of Daily Functioning

Both studies found that sleep quality had stronger associations with affect than did either physical activity or snacking; similarly with learning goal achievement. This finding is important, because very few previous studies have compared strengths of associations among different health behaviors and thus identified important targets for intervention research.

Limitations

The following limitations should be noted. First, most data were obtained by self-report questionnaires. However, the health behaviors assessed by means of repeated self-reports correlated significantly with behavioral measures of physical activity and sleep (actigraph) and with actual snack intake in a controlled setting. Previous research has shown that food intake is mostly underreported (Stubbs et al., 2014). However, given that in the present research self-reported snack intake was associated with behaviorally measured snack intake, it seems likely that our self-report measure represents food intake in a standardized setting reasonably well. Furthermore, the potential influence of confounding factors, such as gender and social status, and response tendency (e.g., the tendency to report higher sleep quality than other participants) were eliminated through the within-person design and person-mean centering. In addition, with the exception of two findings, all results were replicated across the two studies. Second, due to the observational study design, it is impossible to draw inferences about causal relations or to disentangle a chronological order in which behaviors may have influenced each other. Importantly, though, the directional hypotheses formulated were based on theoretical reasoning and previous findings. Third, 10% of the sample dropped out over our longitudinal research. However, this is a low drop-out rate considering that the studies ran for an entire academic year. Fourth, results cannot be generalized to students of other universities or departments.

Conclusions

Single days of better sleep or more physical activity are associated with improved affect and academic performance, two essential aspects of daily functioning in young adults. Importantly, sleep emerged as the strongest predictor of daily functioning. Two intensive longitudinal within-person studies allow comparing a person's "good days" in terms of sleep quality, physical activity, or snacking with their "bad days". The findings thus enhance our understanding of health behaviors and daily functioning beyond cross-sectional, experimental, and between-person studies, which cannot capture the natural variability of a person's health

behavior and daily functioning. Further, within-person designs can provide a basis for prevention and intervention programs, as they focus on changes within the same individual rather than between individuals. For example, the finding that a single night of better sleep or a single day of more physical activity than usual was associated with improved affect and academic performance could be a relevant public health message and inform low-threshold health behavior interventions.

References

Benton, D., Slater, O., & Donohoe, R. T. (2001). The influence of breakfast and a snack on psychological functioning. *Physiology and Behavior, 74*, 559–571. doi: 10.1016/S0031-9384(01)00601-1

Burkhalter, T. M., & Hillman, C. H. (2011). A Narrative Review of Physical Activity, Nutrition, and Obesity to Cognition and Scholastic Performance across the Human Lifespan. *Advances in Nutrition, 2*, 201S-206S. doi: 10.3945/An.111.000331

Busch, V., Loyen, A., Lodder, M., Schrijvers, A. J. P., Yperen, T. A. v., & de Leeuw, J. R. J. (2014). The effects of adolescent health-related behavior on academic performance: A systematic review of the longitudinal evidence. *Review of Educational Research, 84*, 245–274. doi: 10.3102/0034654313518441

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*, 193–213. doi: 10.1016/0165-1781(89)90047-4

Chambers, L., & Yeomans, M. R. (2011). Individual differences in satiety response to carbohydrate and fat. Predictions from the Three Factor Eating Questionnaire (TFEQ). *Appetite, 56*, 316-323. doi: 10.1016/J.Appet.2011.01.003

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research, 1453*, 87–101. doi: 10.1016/J.Brainres.2012.02.068

Chen, K. Y., & Bassett, D. R. (2005). The technology of accelerometry-based activity monitors: Current and future. *Medicine and Science in Sports and Exercise, 37*, S490–S500. doi: 10.1249/01.Mss.0000185571.49104.82

Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Medicine Reviews, 10*, 323–337. doi: 10.1016/J.Smrv.2005.11.001

Desmet, P. M. A., & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite, 50*, 290-301. doi: 10.1016/J.Appet.2007.08.003

Flueckiger, L., Lieb, R., Meyer, A. H., & Mata, J. (2014). How health behaviors relate to academic performance via affect: An intensive longitudinal study. *PloS ONE, 9*, e111080. doi: 10.1371/journal.pone.0111080

Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences, 10*, 141–146.

Hartmann, A. S., Rief, W., & Hilbert, A. (2012). Laboratory snack food intake, negative mood, and impulsivity in youth with ADHD symptoms and episodes of loss of control eating. Where is the missing link? *Appetite, 58*, 672-678. doi: 10.1016/J.Appet.2012.01.006

Hewlett, P., Smith, A., & Lucas, E. (2009). Grazing, cognitive performance and mood. *Appetite, 52*, 245–248. doi: 10.1016/J.Appet.2008.09.008

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*, 58–65. doi: 10.1038/Nrn2298

Hogan, C. L., Mata, J., & Carstensen, L. L. (2013). Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychology and Aging, 28*, 587–594. doi: 10.1037/a0032634

Hormes, J. M., & Rozin, P. (2011). The temporal dynamics of ambivalence: Changes in positive and negative affect in relation to consumption of an "emotionally charged" food. *Eating Behaviors, 12*, 219-221. doi: 10.1016/J.Eatbeh.2011.02.001

Jacobs, D. R., Ainsworth, B. E., Hartman, T. J., & Leon, A. S. (1993). A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Medicine and Science in Sports and Exercise, 25*, 81–91. doi: 10.1249/00005768-199301000-00012

Kanning, M. K., Ebner-Priemer, U. W., & Schlicht, W. M. (2013). How to investigate within-subject associations between physical activity and momentary affective states in everyday life: A position statement based on a literature overview. *Frontiers in Psychology, 4*, 1–16. doi: 10.3389/fpsyg.2013.00187

Lucke, J., & Partridge, B. (2013). Towards a smart population: A public health framework for cognitive enhancement. *Neuroethics, 6*, 419–427. doi: 10.1007/s12152-012-9167-3

Lyubomirsky, S., King, L., & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin, 131*, 803–855. doi: 10.1037/0033-2909.131.6.803

Macht, M., & Dettmer, D. (2006). Everyday mood and emotions after eating a chocolate bar or an apple. *Appetite, 46*, 332-336. doi: 10.1016/J.Appet.2006.01.014

Marmeleira, J. (2013). An examination of the mechanisms underlying the effects of physical activity on brain and cognition. *European Review of Aging and Physical Activity, 10*, 83–94. doi: 10.1007/S11556-012-0105-5

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gottlib, I. H. (2012). Walk on the bright side: Physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*, 297–308. doi: 10.1037/a0023533

Miller, R., Benelam, B., Stanner, S., & Buttriss, J. (2013). Is snacking good or bad for health: An overview. *Nutrition Bulletin, 38*, 302–322. doi: 10.1111/nbu.12042

Molenaar, P. C. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement, 2*, 201–218. doi: 10.1207/s15366359mea0204_1

Morisano, D., Hirsh, J. B., Peterson, J. B., Pihl, R. O., & Shore, B. M. (2010). Setting, elaborating, and reflecting on personal goals improves academic performance. *Journal of Applied Psychology, 95*, 255–264. doi: 10.1037/A0018478

Muthén, L. K., & Muthén, B. O. (1998–2012). *Mplus user's guide (7th ed.)*. Los Angeles, CA: Muthén & Muthén.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods Instruments & Computers, 36*, 717-731. doi: 10.3758/Bf03206553

Preacher, K. J., Zyphur, M. J., & Zhang, Z. (2010). A general multilevel SEM framework for assessing multilevel mediation. *Psychological Methods, 15*, 209–233. doi: 10.1037/A0020141

Reed, J., & Ones, D. S. (2006). The effect of acute aerobic exercise on positive activated affect: A meta-analysis. *Psychology of Sport and Exercise, 7*, 477–514. doi: 10.1016/J.Psychsport.2005.11.003

Richard, E. M., & Diefendorff, J. M. (2011). Self-regulation during a single performance episode: Mood-as-information in the absence of formal feedback. *Organizational Behavior and Human Decision Processes, 115*, 99–110. doi: 10.1016/J.Obhdp.2010.11.008

Riemann, D., & Backhaus, J. (1996). *Behandlung von Schlafstörungen [Treatment of sleep disorders]*. Weinheim, Germany: Beltz Psychologie-Verlag-Union.

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin, 130*, 261–288. doi: 10.1037/0033-2909.130.2.261

Roecke, C. (2006). *Intraindividual variability in positive and negative affect.* Doctoral dissertation, Freie Universität Berlin, Germany. Retrieved from http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002464

Schoenborn, C. A. (1986). Health habits of U.S. adults, 1985: The 'Alameda 7' revisited. *Public Health Reports, 101*, 571–580.

Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry, 14*, 296–303. doi: 10.1207/S15327965pli1403&4_20

Smith, A. P. (2011). Snacking habit, mental health, and cognitive performance. *Current Topics in Nutraceutical Research, 9*, 47–51. doi: 10.3390/nu3050515#sthash.haoOeQkn.dpuf

Smith, A. P., & Wilds, A. (2009). Effects of cereal bars for breakfast and mid-morning snacks on mood and memory. *International Journal of Food Sciences and Nutrition, 60*, 63-69. doi: 10.1080/09637480802438305

Sonnentag, S., Binnewies, C., & Mojza, E. J. (2008). "Did you have a nice evening?" A day-level study on recovery experiences, sleep and affect. *Journal of Applied Psychology, 93*, 674–683. doi: 10.1037/0021-9010.93.3.674

Steenhuis, I. (2009). Guilty or not? Feelings of guilt about food among college women. *Appetite, 52*, 531-534. doi: 10.1016/J.Appet.2008.12.004

Stubbs, R. J., O'Reilly, L. M., Whybrow, S., Fuller, Z., Johnstone, A. M., Livingstone, M. B. E., . . . Horgan, G. W. (2014). Measuring the difference between actual and reported food intakes in the context of energy balance under laboratory conditions. *British Journal of Nutrition, 111*, 2032–2043. doi: 10.1017/S0007114514000154

von Dawans, B., Kirschbaum, C., & Heinrichs, M. (2011). The Trier Social Stress Test for Groups (TSST-G): A new research tool for controlled simultaneous social stress exposure in a group format. *Psychoneuroendocrinology, 36*, 514–522. doi: 10.1016/j.psyneuen.2010.08.004

Walsh, R. (2011). Lifestyle and mental health. *American Psychologist, 66*, 579–592. doi: 10.1037/A0021769

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070. doi: 10.1037/0022-3514.54.6.1063

Weikert, M., Motl, R. W., Suh, Y., McAuley, E., & Wynn, D. (2010). Accelerometry in persons with multiple sclerosis: Measurement of physical activity or walking mobility? *Journal of the Neurological Sciences, 290*, 6–11. doi: 10.1016/j.jns.2009.12.021

Wichers, M., Peeters, F., Rutten, B. P. F., Jacobs, N., Derom, C., Thiery, E., . . . van Os, J. (2012). A time-lagged momentary assessment study on daily life physical activity and affect. *Health Psychology, 31*, 135–144. doi: 10.1037/A0025688

Wong, M. L., Lau, E. Y. Y., Wan, J. H. Y., Cheung, S. F., Hui, C. H., & Mok, D. S. Y. (2013). The interplay between sleep and mood in predicting academic functioning, physical health and psychological health: A longitudinal study. *Journal of Psychosomatic Research, 74*(4), 271-277.

World Health Organization [WHO]. (2002). *The world health report 2002: Reducing risks, promoting healthy life*. Geneva, Switzerland: Author.

Zizza, C., Siega-Riz, A. M., & Popkin, B. M. (2001). Significant increase in young adults' snacking between 1977–1978 and 1994–1996 represents a cause for concern! *Preventive Medicine, 32*, 303–310. doi: 10.1006/Pmed.2000.0817

Table 1

Sample Characteristics and Intraclass Correlations (ICC)

	Study 1 (*N* = 292)	Study 2 (*N* = 304)
Gender (women %)	75.0%	64.1%
Age (*M, SD*)	20.7 (2.5)	21.4 (5.1)
Sleep quality (*M, SD*)	3.6 (1.0)	3.6 (1.0)
ICC	0.29	0.25
Physical activity (*M, SD*)	368.1 (464.3)	422.5 (515.1)
ICC	0.33	0.38
Snacking (*M, SD*)	2.2 (2.2)	2.3 (2.2)
ICC	0.41	0.38
Positive affect (*M, SD*)	4.9 (1.4)	4.9 (1.4)
ICC	0.43	0.40
Negative affect (*M, SD*)	2.3 (1.3)	2.2 (1.3)
ICC	0.39	0.38
Learning goal achievement (*M, SD*)	2.1 (1.3)	2.2 (1.2)
ICC	0.29	0.23

Note: ICC measures whether observations from different persons are more discrepant from one another than observations within the same person, ranges from 0 (*complete independence of observations*) to 1 (*complete dependence*). For example, 29% of the variability in sleep quality stems from differences between participants. *Sleep quality* was rated on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*). Minutes of mild, moderate, and strenuous *physical activity* were converted into metabolic equivalents. Experience of *positive and negative affect* was rated on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*). *Learning goal achievement* was rated on a 5-point Likert scale from 0 (*not at all*) to 4 (*completely).*

Table 2

Direct, Total, and Mediated Effects of Sleep Quality, Physical Activity, and Snacking on Learning Goal Achievement via Positive and Negative Affect on a Day-to-Day Level for Study 1 and Study 2

Predictor	Sleep quality				Sleep quality				Physical activity				Physical activity				Snacking				Snacking			
Mediator	Positive affect				Negative affect				Positive affect				Negative affect				Positive affect				Negative affect			
	Study 1		Study 2		Study 1		Study 2		Study 1		Study 2		Study 1		Study 2		Study 1		Study 2		Study 1		Study 2	
	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*
a	0.25 (0.02)	<.001	0.21 (0.02)	<.001	–0.08 (0.01)	<.001	–0.07 (0.01)	<.001	0.14 (0.02)	<.001	0.18 (0.02)	<.001	–0.03 (0.00)	<.001	–0.03 (0.01)	<.001	0.05 (0.02)	.004	0.03 (0.02)	.108	–0.00 (0.01)	.396	0.01 (0.01)	.219
b	0.11 (0.02)	<.001	0.12 (0.01)	<.001	–0.34 (0.05)	<.001	–0.40 (0.04)	<.001	0.11 (0.02)	<.001	0.12 (0.01)	<.001	–0.34 (0.05)	<.001	–0.40 (0.04)	<.001	0.11 (0.02)	<.001	0.12 (0.01)	<.001	–0.34 (0.05)	<.001	–0.40 (0.04)	<.001
ab	0.03 (0.00)	<.001	0.03 (0.00)	<.001	0.03 (0.00)	<.001	0.03 (0.00)	<.001	0.02 (0.00)	<.001	0.02 (0.00)	<.001	0.01 (0.00)	<.001	0.01 (0.00)	<.001	0.01 (0.00)	.007	0.00 (0.00)	.104	0.00 (0.00)	.405	–0.00 (0.00)	.225
Mediated proportion (%)	42%		53%		39%		55%		–		48%		–		25%		–		–		–		–	
c	0.06 (0.01)	<.001	0.05 (0.01)	.001	0.06 (0.01)	<.001	0.05 (0.01)	.001	0.01 (0.02)	.535	0.04 (0.02)	.006	0.01 (0.02)	.533	0.04 (0.02)	.006	–0.01 (0.02)	.661	0.01 (0.02)	.475	–0.01 (0.02)	.659	0.01 (0.02)	.478
c'	0.04 (0.01)	.007	0.02 (0.01)	.127	0.04 (0.01)	.005	0.02 (0.01)	.134	–0.01 (0.02)	.698	0.02 (0.02)	.150	0.00 (0.02)	.930	0.03 (0.02)	.038	–0.01 (0.02)	.449	0.01 (0.02)	.605	–0.01 (0.02)	.598	0.01 (0.02)	.380

Note. Ratios are based on absolute values of direct and indirect effects: e.g., positive affect mediated 42% of the total effect between sleep quality and learning goal achievement. β = standardized regression coefficient; *SE* = standard error; *a* = path from predictor to mediator; *b* = path from mediator to outcome; *ab* = indirect effect; *c* = total effect = *ab* (indirect effect) + *c'* (direct effect); *c'* = direct effect = path from predictor to outcome after controlling for the mediator.

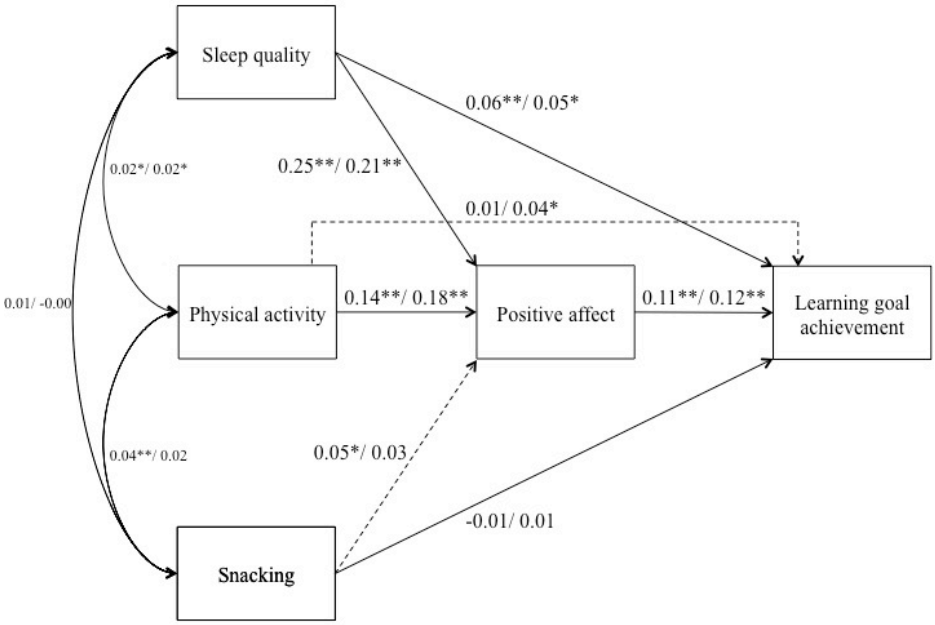

Figure 1a: Positive affect as mediator

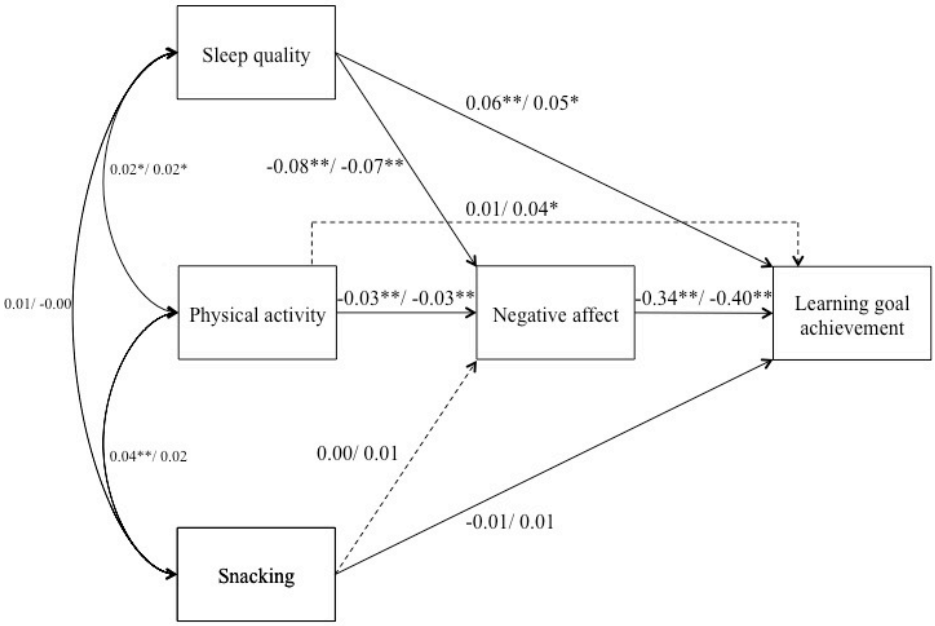

Figure 1b: Negative affect as mediator

Figure. Mediation model of health behaviors on learning goal achievement via affect on the within-person level. Predictors were allowed to correlate. Standardized Beta-estimates are presented for Study 1 and Study 2, respectively (e.g., 0.25**/ 0.21** = Study 1/Study 2). Solid line: associations replicated for Study 1 and Study 2; dashed line: associations not replicated or lack of associations replicated; * $p < .05$; ** $p < .001$.

Appendix C

The Importance of Physical Activity and Sleep for Affect on Stressful Days:

Two Intensive Longitudinal Studies.

Flueckiger, L., Lieb, R., Meyer, A., Witthauer, C., & Mata, J.

(submitted to *Emotion*)

The importance of physical activity and sleep for affect on stressful days: Two intensive longitudinal studies

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Abstract

Objective: The aim of the present article is to investigate the impact of naturally occurring stress on the association between health behaviors such as physical activity, sleep quality, and snacking with affect in the context of everyday life in young adults. ***Methods***: In two intensive longitudinal studies with up to 65 assessment days over an entire academic year, students (Study 1: $N = 292$; Study 2: $N = 304$) reported stress intensity, sleep quality, physical activity, snacking, positive and negative affect. Data were analyzed using multilevel regression analyses. ***Results:*** On days with higher than usual stress, increased physical activity was more strongly associated with higher positive affect (Study 1) and lower negative affect (Study 1 and 2) than on days with lower than usual stress. Better sleep quality was more strongly associated with higher positive affect (Study 1 and 2) and lower negative affect (Study 2) on higher compared to lower than usual stressful days. The association between daily snacking and positive or negative affect did not differ with respect to daily stress (Study 1 and 2). ***Conclusions:*** On stressful days, physical activity or good sleep quality may be a valuable resource to buffer the adverse effects of stress on affect in young adults. These findings may be a relevant public health message to support young adults during stressful times.

Keywords: Physical activity, sleep quality, snacking, everyday stress, positive and negative affect

Introduction

Nearly everyone encounters stressors in daily life such as being late for a meeting, work deadlines, or a disagreement with a significant other every day. These daily stressors can have a strong impact on daily affect (Jacobs et al., 2007; O'hara, Armeli, Boynton, & Tennen, 2014), well-being (Almeida, 2005) or mental health, sometimes even more than major life events (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982; Thoits, 2010). Therefore, identifying behaviors that may help people to reduce the adverse effect of everyday stress is of considerable importance.

One resource that has been proposed to buffer stress is physical activity. Prior experimental studies showed that the association between stress – assessed as either stressful events (Norris, Carroll, & Cochrane, 1992; Roth & Holmes, 1987) or induced throuhg a stress test (Childs & de Wit, 2014; Mata, Hogan, Joormann, Waugh, & Gotlib, 2013; Rejeski, Thompson, Brubaker, & Miller, 1992; Rimmele et al., 2007) – and depressive symptoms was weaker in physically active subjects compared to the control group. Cross-sectional (Ensel & Lin, 2004; Roth & Holmes, 1985) and few longitudinal studies (Klaperski, Seelig, & Fuchs, 2012) showed that the association between increased stress and increased depressive symptomes was weaker for more physically active compared to less physically active employees and young adults. However, this finding could not be confirmed in adolescents (Moksnes, Moljord, Espnes, & Byrne, 2010).

Existing evidence has mainly tested the stress-buffering role of physical activity on depressive symptoms focusing on differences between individuals. This between person perspective, however, offers only a snapshot by reflecting a person's behavior and well-being as rather stable trait. Especially daily stress shows a high variability within the same person over time, which cannot be captured by cross-sectional or experimental between-person studies. These between-person associations may be different from associations on the within-person level (Molenaar, 2004). Hence, how stress, physical activity, and affect unfold within a

person in the context of everyday life is unclear. Although results by Klaperski and colleagues (2012) were based on longitudinal data, these could not fully grasp everyday life variability, as the two assessment points were ten months apart.

Apart from scarce longitudinal data that support the health-protective association between habitual physical activity and well-being during stressful times (Klaperski et al., 2012), it is unknown whether health behaviors such as sleep quality or snacking could also serve as a potential stress-buffer. Previous research has shown that day-to-day health behaviors such as sleep duration (Wrzus, Wagner, & Riediger, 2014) and sleep quality (Flueckiger, Lieb, Meyer, & Mata, 2014; Galambos, Dalton, & Maggs, 2009) were associated with increased positive and decreased negative affect. Snacking has been associated with pleasurable emotions (Desmet & Schifferstein, 2008) and increased positive affect in healthy young adults in experimental settings (Benton, Slater, & Donohoe, 2001) as well as in everyday life with controlled snack administration (Macht & Dettmer, 2006). However, some experimental research has shown that snacking can also be followed by guilt (Macht & Dettmer, 2006; Steenhuis, 2009) and reduced positive affect (Hormes & Rozin, 2011). Hence, it is unclear whether snacking may have a potential stress-buffering or rather deteriorating effect on affect during stressful times whereas prior research supported a positive association between sleep quality and affect indicating a potential stress-buffering effect of sleep quality.

Positive and negative affect may change from day to day (Roecke, 2006) and may therefore be sensitive to changes in daily life. Daily behavior is a facet of general behavior. Thus, the daily perspective is an important approach as short-term changes make up long-term behavior (change). Enduring affect has been associated with various life domains such as emotion regulation (Brans, Koval, Verduyn, Lim, & Kuppens, 2013), health, success (Lyubomirsky, King, & Diener, 2005), and reduced mortality (Chida & Steptoe, 2008) underlining the potential benefit of regulating positive affect in everyday life for long-term outcomes. Importantly, health behaviors also tend to vary in daily life. Thus, health behaviors

are in strong contrast to stable between-person characteristics such as neuroticism (Mroczek & Almeida, 2004), self-esteem, or social support (Delongis, Folkman, & Lazarus, 1988) that have been identified as potential stress-buffer.

Based on this rationale, the present research used two intensive longitudinal studies over an entire academic year identifying health behaviors that may help young adults to sustain their affect on stressful days. The aim of the current article was to examine the impact of stress on the association between physical activity, sleep quality, and snacking on positive and negative affect in everyday life. Specifically, we hypothesize that

(1) The more stressful than usual a day is, the stronger the association between higher physical activity and higher positive affect. The more stressful than usual a day is, the stronger the association between higher physical activity and lower negative affect.

(2) The more stressful than usual a day is, the stronger the association between higher sleep quality and higher positive affect. The more stressful than usual a day is, the stronger the association between higher sleep quality and lower negative affect.

Concerning the role of snacking for affect, some literature suggested positive affect after snacking (e.g., Desmet & Schifferstein, 2008), some established facets of negative affect after snacking (e.g., Steenhuis, 2009). Therefore, we propose the following two competing hypotheses for the association between snacking and affect under varying stress-levels:

(3a) The more stressful than usual a day is, the stronger the association between more snacking and higher positive affect. The more stressful than usual a day is, the stronger the association between more snacking and lower negative affect.

(3b) The more stressful than usual a day is, the stronger the association between more snacking and lower positive affect. The more stressful than usual a day is, the stronger the association between more snacking and higher negative affect.

Methods

Study 1

Design and Procedure

Data were obtained from an intensive longitudinal survey during the freshman year at the University of Basel, Switzerland from November 2011 to July 2012. Participants were recruited through announcements made during introductory lectures that are obligatory for first-year students majoring in law, natural sciences, or psychology. Interested students indicated their e-mail address and received an e-mail with a link to an online entry assessment. Detailed information about the study was provided at the first page of the entry assessment. After giving informed consent, they were invited to participate in 61 short online assessments, each taking on average 5.30 minutes (*SD* = 1.38) to complete. The first 28 assessment invitations were mailed every six days. This six-day interval during the first half of the academic year was chosen to cover all weekdays about equally often, keep participant's burden acceptable, and consequently minimize study drop-out. The remaining 33 assessment invitations were sent out on consecutive days to get a better snapshot of daily variability of affect, stress, and health behaviors. Finally, participants completed an online exit assessment.

In each assessment, participants provided their personal code. This code was used to link individual participants' completed online assessments. Participants were never asked to provide any information that would allow them to be identified; personal codes could not be linked to e-mail addresses.

Additionally, participants were invited to a 3-hour laboratory session. As the aim of this article was to elucidate the day-to-day associations between health behaviors, stress, and affect, the laboratory between-person data were not considered in the present analyses.

All participants received financial compensation for their participation. Psychology students could choose between financial compensation, equivalent course credits, or a mix of

both. The local ethics committee, Ethikkommission beider Basel, Switzerland, approved the study, reference number EK: 48/11.

Participants

A total of 323 participants answered the daily online assessments. Of these, 31 (10%) were excluded from the analyses because they completed only three or fewer online assessments, not allowing statistical analyses on cubic temporal associations. Thus, the final sample was $N = 292$. The 292 participants provided a total of 11,050 responses over the 61 assessments; on average, each participant completed $M = 38$ assessments ($SD = 18$; range: 4–61), which reflects a compliance rate of 62% (range: 7–100%).

First-year university students are a particularly suitable population to test the present hypotheses: First, they experience comparable amounts of stressful (e.g., examination periods) and non-stressful times (e.g., vacation periods). They are thus in a natural, but relatively controlled, setting. Second, most students are of similar educational background and age; hence, they represent a relatively homogeneous population. Third, all university students have Internet access through the university; therefore, online assessment is not a selection bias.

Because within-person analyses focus on associations within the same person—in our case, comparing individual reports across the days over the study period—we did not consider gender differences or other between-person variables as variables of interest: Between-person predictors are time-invariant and do not affect within-person analyses that compare a person with herself across various measurements (Bolger, Davis, & Rafaeli, 2003).

Measures

Entry and Exit Questionnaire. *Sociodemographic information* was obtained in the entry assessment.

Day-level Questionnaire. *Physical activity* was evaluated with the Godin Leisure-Time Exercise Questionnaire (Godin & Shephard, 1985), adapted to the daily online

questionnaire format (see Mata et al., 2012). Participants were asked to indicate the number of minutes engaged in mild (minimal effort; e.g., easy walking), moderate (not exhausting; e.g., fast walking), and strenuous exercise (heart beats rapidly; e.g., running) during the last 24 hours. The daily minutes of mild, moderate, and strenuous physical activity were weighted by metabolic equivalents and summed up to a total daily leisure activity score. High scores reflect high levels of physical activity (Godin & Shephard, 1985). The original Godin Leisure-Time questionnaire has shown adequate concurrent validity with accelerometry (Jacobs, Ainsworth, Hartman, & Leon, 1993).

Sleep quality was assessed with the item from the German version of the Pittsburgh Sleep Quality Index (Riemann & Backhaus, 1996) that shows the highest correlation with the final score of the full scale (single item–total correlation), $r = 0.83$ (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Participants indicated their sleep quality during the previous night on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*).

Snacking was characterized as every snack outside main meals. Participants reported the number of high-fat sweet snacks (e.g., chocolate, ice cream), high-fat savory snacks (e.g., chips, pizza), low-fat savory snacks (e.g., bread, pretzel), and other snacks. The number of each snack category was then summed up to a daily snacking score.

Stress was obtained by asking participants whether they experienced a stressful event during the last 24 hours and if yes, to indicate how stressful this event was experienced on a 5-point Likert scale from 1 (*little stressful*) to 5 (*very stressful*). They could report up to three stressful events in the morning, afternoon, and evening. If participants experienced no stressful event during the last 24 hours, they skipped this question. The stress intensity score was calculated as the mean intensity of all stressful events on a day.

Positive and negative affect were assessed with the German version of the pleasantness scale (Roecke, 2006), a six-item instrument that has been shown to lead to comparable results as the Positive and Negative Affect Schedule (PANAS; Watson, Clark, &

Tellegen, 1988) in a nonclinical sample (Roecke, 2006). Participants rated on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*) the extent to which they had felt each of the following emotions during the last 24 hours: happy, content, cheerful, sad, downhearted, and frustrated. Cronbach's alpha for internal consistency reliabilities was $\alpha = .94$ ($M = 14.54$, $SD = 4.18$) for positive affect and $\alpha = .85$ ($M = 7.00$, $SD = 3.96$) for negative affect, calculated over all 61 measurement occasions.

Statistical Analyses

As repeated measurement points were nested within participants, data were analyzed using multilevel regression analyses. This method enabled us to test the within-person association between daily health behaviors, daily stress, and daily affect as well as handling appropriately missing data and varying time intervals (Raudenbush & Bryk, 2002). Predictor variables were centered around each individual's mean, allowing to test whether deviations from, for example, an individual's average physical activity was associated with positive affect on that day. Person-mean centering additionally reduces the impact of multicollinearity between moderator and predictor (Tabachnick & Fidell, 2013), which can rarely be avoided entirely (Kraemer & Blasey, 2004).

Multilevel regression analyses were conducted for each predictor separately (physical activity, sleep quality, and snacking) and each outcome (positive and negative affect). Our model contained as fixed effects the respective health behavior as predictor, stress as moderator, and the interaction between the two. Due to the symmetry of the interaction term the distinction between predictor and moderator is arbitrary (Preacher, Curran, & Bauer, 2006). To account for potential nonlinear trends of affect over time, we additionally included as temporal trend expressed by linear, quadratic, and cubic terms in the model. We used a random slopes model in which intercept and the slopes of time and moderator were allowed to vary between individuals. As physical activity, snacking, negative affect, and stress were not normally distributed, we conducted logarithmic transformations for physical activity and

stress and square root transformations for snacking and negative affect to approximate normal distributions. The software R (R version 2.15.1) was used for all analyses.

Study 2

Design and Procedure

Study 2 is an extension of Study 1. The data were obtained between October 2012 and July 2013. Participants were recruited through flyers and announcements made during lectures in several departments. After detailed information about the study and informed consent, participants were invited to 65 short online assessments, each taking on average 5.38 minutes (*SD* = 1.23) to complete. The first 35 invitations were sent out every six days; the following 30 on consecutive days. Additionally, participants were invited to a laboratory session including ten minutes in which they could eat a variety of snacks (high-fat sweet, low-fat sweet, high-fat savory, low-fat savory) ad libitum; a subsample of participants wore actigraph watches for one week measuring sleep and physical activity.

Participants

A total of 337 first-year university students took part. Of these, 33 (10%) were excluded due to only three or fewer completed daily assessments, not allowing statistical analyses on cubic temporal associations. Thus, the final sample included *N* = 304. These participants provided 11,857 responses over the 65 assessments; on average, each participant completed *M* = 39 assessments (*SD* = 19; range: 4–65) representing a compliance rate of 60% (range: 6–100%). As in Study 1, between-person factors were not controlled for due to the within-person design.

Measures

All measured used are listed below. For measures already described for Study 1 above, only reliability is reported.

Entry and Exit Questionnaire. *Sociodemographic information* was obtained in the entry assessment.

Day-level Questionnaire. *Sleep quality, physical activity, snacking*, *positive and negative affect* (Cronbach's alpha for internal consistency reliabilities for positive affect: α = .92, *M* = 14.53, *SD* = 4.06; negative affect α = .85, *M* = 6.59, *SD* = 3.83, calculated for all 65 measurement occasions) were assessed with the same scales as in Study 1. In addition to Study 1, self-reported data were validated using behavioral data: Average self-reported snacking over the 65 assessment days was associated with behaviorally measured snack intake assessed in the laboratory session (high-fat sweet snacks: $r = .25$, $p = .002$; high-fat savory snacks: $r = .31$, $p < .001$; low-fat savory snacks: $r = .28$, $p < .001$). Self-reported sleep duration and physical activity were associated with sleep duration ($\beta = 0.75$, $SE = 0.04$, $p < .001$) and physical activity ($\beta = 0.18$, $SE = 0.06$, $p = .003$) measured by actigraph watches worn during seven consecutive days (for more details see Flueckiger, Lieb, Meyer, Witthauer, Mata, under review).

Stress was assessed by asking participants whether they experienced stressful events during the last 24 hours on a 6-point Likert scale from 0 (not experienced) to 5 (very stressful). Participants were asked to classify their stressful events in five categories based on previous research (e.g., O'Connor, Jones, Conner, McMillan, & Ferguson, 2008): interpersonal (e.g., argument with partner, family problem), study-/work-related (e.g., difficult task, late for meeting), ego-threatening (e.g., examination, job interview), health-related (e.g., being sick, tired), and others (e.g., computer problems, shopping). For each category, participants could indicate up to two stressful events. Stress intensity was calculated as the mean intensity of all stressful events reported on a day.

Statistical Analyses

The same multilevel regression analyses as reported for Study 1 were used.

Results

Sample characteristics are displayed in Table 1. The proportion of female participants was high in both studies. There was considerable variability in reported physical activity in

both studies. Participants reported relatively high sleep quality, a medium amount of snacking, average positive affect, and relatively low negative affect in both studies. More stress was reported in Study 1 than in Study 2.

Results for Study 1 and Study 2 are presented in Table 2. In line with our hypotheses, both studies showed that on days on which participants reported better sleep quality or increased physical activity than usual (i.e., higher than their personal average), they also reported increased positive affect and decreased negative affect, respectively. In both studies, daily snacking was associated with increased positive affect, but not with negative affect. Consistent with our hypotheses, both studies showed that on days on which participants reported more stress than usual, they also reported decreased positive affect and increased negative affect, respectively. Note that since predictors were person-mean centered, main effects can be interpreted in the presence of the interaction term (in our article, we additionally analyzed the main effects without including the interaction term and leading to comparable results).

Figure 1 shows the interaction between health behaviors and stress on positive and negative affect for Study 1 and Study 2. In Study 1, higher daily physical activity was more strongly associated with higher positive affect the more stressful than usual a day was experienced. Study 2 showed a similar pattern, but the interaction between positive affect and stress was short off being significant (95% CI [–0.01, 0.73]; $p = .057$). In both studies, the association between higher physical activity and lower negative affect was stronger the more stressful than usual a day was. Higher daily sleep quality was more strongly associated with higher positive affect (Study 1 and 2) and lower negative affect (Study 2) the more stressful than usual a day was experienced. In both studies, the association between daily snacking and affect did not differ for different levels of daily stress. Importantly, the association between stress and affect was larger than the association between physical activity and sleep quality with affect.

Discussion

Findings from the present intensive longitudinal studies suggest that different health behaviors may buffer the detrimental effects of stress on positive and negative affect in young adults' daily life. On days with more stress than usual, engaging in physical activity or experiencing higher sleep quality was more strongly associated with higher positive and lower negative affect than on days with lower than usual stress; there was no such association for snacking. In other words, on more stressful days physical activity and sleep quality, but not snacking emerged as potential protective factors against increased negative and decreased positive affect. These findings extend prior research in two important aspects: First, the present two studies focused on naturally occurring variations in stress, health behaviors, and affect within the same person whereas previous research mainly focused on between-person differences (e.g., Ensel & Lin, 2004) and therefore could only inform about a snapshot of an individual's behavior. Second, besides the previously explored stress-buffering role of physical activity (mostly in experimental or cross-sectional studies), the current article examined further health behaviors that are central to everyday life, namely sleep quality and snacking.

The higher daily stress, the stronger the association between more physical activity and increased positive and decreased negative affect. Importantly, the association with positive affect was only established in one of the two studies. One potential explanation for the discrepant results between the studies could be due to methodological differences, i.e., the distinct operationalizations of daily stress. Therefore, further research should clarify the role of stress in the association between physical activity and positive affect in everyday life. However, the present results mainly converge with previous experimental (e.g., Mata et al., 2013) and cross-sectional studies (e.g., Ensel & Lin, 2004). One potential mechanism of how physical activity may change the association between stress and affect could be a reduced cortisol response to stress: Daily stress and negative affect have been associated with a higher

cortisol level, positive affect with a lower cortisol level (Smyth et al., 1998). Importantly, acute physical activity has been associated with lower cortisol responses after stress (Zschucke, Renneberg, Dimeo, Wustenberg, & Strohle, 2015).

On days with higher stress than usual, having a better sleep quality than usual was associated with higher positive and lower negative affect. The asscociation with negative affect was only established in one study. Similarly to the reasoning mentioned above, the distinct operationalization of daily stress might explain the difference between the two studies, i.e., a potential underestimation of stress in Study 1 and hence, the potential interaction could not have been established. Therefore, further research is needed to clarify the role of daily stress in the association between sleep quality and negative affect. A potential mechanism for the link between sleep, stress, and affect could be changes in the amygdala activation (Davis & Whalen, 2001), which may be involved in the hypothalamo-pituitary-adrenal system (Muscatell & Eisenberger, 2012). Stress (Roozendaal, McEwen, & Chattarji, 2009) as well as sleep deprivation (Kahn, Sheppes, & Sadeh, 2013) have been associated with amygdala activation. For example, Minkel and colleagues (2014) showed that sleep deprived individuals had an elevated cortisol response after stress, which migth be due to an increased amygdala activation.

Contrary to our assumptions concerning snacking, both studies showed that the association between daily snacking and positive and negative affect did not differ with respect to experienced stress. These results indicate that neither a potential stress-buffering nor a deteriorating effect of snacking on affect was supported. One possible reason could be that the effect of snacking might be relatively weak and short-lived in comparison to physical activity and sleep quality. In contrast, increased daily snacking was associated with increased positive affect, however this association was limited and weaker compared to physical activity and sleep quality. Future research could investigate the association between snacking, stress, and affect with a more intense study design (e.g., several assessments per day) to capture such

potential short-term associations. For example, differences in the association between stress and affect have been found, depending on when a stressful event occurred (Wrzus, Luong, Wagner, & Riediger, 2014).

Limitations

Most data were obtained by self-report data. However, self-reported health behaviors correlated with behavioral measures of physical activity and sleep obtained by actigraph and actual snack intake in a laboratory setting. Furthermore, due to the within-person design and person-mean centering potential influence of confounding factors, such as gender or social status, and response tendency were eliminated. Additionally, with the exception of two results (which showed a similar tendency), all findings were replicated across the two studies. A second limitation is due to the observational study design, which does not allow drawing causal inferences or disentangling the chronological order in which behaviors may have influenced each other. Third, the dropout rate was 10%. However, this is a comparably low dropout rate considering the study durations of almost one year. Finally, results cannot be generalized to other universities and ages.

Conclusions

On days with higher stress than ususal, engaging in physical activity or good sleep quality may serve as stress-buffer for affect, which is an important indicator of mental well-being. The association between stress and affect was stronger than the association between health behaviors and affect, indicating that increased physical activity and sleep quality cannot completely offset the adverse effect of daily stress. To recover from daily stress, individuals may need to mobilize further resources besides physical activity and good sleep quality. Nevertheless, the current findings extend previous between-person studies by elucidating the naturally occurring day-to-day dynamics of stress, health behaviors, and affect. Such within-person results may have important practical implications by providing information for prevention and intervention programs as they examine how an individual

changes if the situation or the behavior changes. For example, one relevant public health message could be that especially on more stressful days than usual, young adults may benefit more from being physically active or good sleep quality, which in turn may be associated with long-term mental and physical health.

References

Almeida, D. M. (2005). Resilience and vulnerability to daily stressors assessed via diary methods. *Current Directions in Psychological Science, 14*, 64–68. doi: 10.1111/J.0963-7214.2005.00336.X

Benton, D., Slater, O., & Donohoe, R. T. (2001). The influence of breakfast and a snack on psychological functioning. *Physiology and Behavior, 74*, 559–571. doi: 10.1016/S0031-9384(01)00601-1

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology, 54*, 579-616. doi: 10.1146/Annurev.Psych.54.101601.145030

Brans, K., Koval, P., Verduyn, P., Lim, Y. L., & Kuppens, P. (2013). The regulation of negative and positive affect in daily life. *Emotion, 13*, 926–939. doi: 10.1037/A0032400

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*, 193–213. doi: 10.1016/0165-1781(89)90047-4

Chida, Y., & Steptoe, A. (2008). Positive psychological well-being and mortality: A quantitative review of prospective observational studies. *Psychosomatic Medicine, 70*, 741–756. doi: 10.1097/Psy.0b013e31818105ba

Childs, E., & de Wit, H. (2014). Regular exercise is associated with emotional resilience to acute stress in healthy adults. *Frontiers in Physiology, 5*. doi: 10.3389/Fphys.2014.00161

Davis, M., & Whalen, P. J. (2001). The amygdala: Vigilance and emotion. *Molecular Psychiatry, 6*, 13–34. doi: 10.1038/Sj.Mp.4000812

DeLongis, A., Coyne, J. C., Dakof, G., Folkman, S., & Lazarus, R. S. (1982). Relationship of daily hassles, uplifts, and major life events to health status. *Health Psychology, 1*(2), 119.

Delongis, A., Folkman, S., & Lazarus, R. S. (1988). The impact of daily stress on health and mood - Psychological and social resources as mediators. *Journal of Personality and Social Psychology, 54*, 486–495. doi: 10.1037/0022-3514.54.3.486

Desmet, P. M. A., & Schifferstein, H. N. J. (2008). Sources of positive and negative emotions in food experience. *Appetite, 50*, 290–01. doi: 10.1016/J.Appet.2007.08.003

Ensel, W. M., & Lin, N. (2004). Physical fitness and the stress process. *Journal of Community Psychology, 32*, 81–101. doi: 10.1002/Jcop.10079

Flueckiger, L., Lieb, R., Meyer, A. H., & Mata, J. (2014). How health behaviors relate to academic performance via affect: An intensive longitudinal study. *PLOS ONE, 9*, e111080. doi: 10.1371/journal.pone.0111080

Galambos, N. L., Dalton, A. L., & Maggs, J. L. (2009). Losing sleep over it: Daily variation in sleep quantity and quality in Canadian students' first semester of university. *Journal of Research on Adolescence, 19*, 741–761. doi: 10.1111/j.1532-7795.2009.00618.x

Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences, 10*, 141–146.

Hormes, J. M., & Rozin, P. (2011). The temporal dynamics of ambivalence: Changes in positive and negative affect in relation to consumption of an "emotionally charged" food. *Eating Behaviors, 12*, 219–221. doi: 10.1016/J.Eatbeh.2011.02.001

Jacobs, D. R., Ainsworth, B. E., Hartman, T. J., & Leon, A. S. (1993). A simultaneous evaluation of 10 commonly used physical activity questionnaires. *Medicine and Science in Sports and Exercise, 25*, 81–91. doi: 10.1249/00005768-199301000-00012

Jacobs, N., Myin-Germeys, I., Derom, C., Delespaul, P., van Os, J., & Nicolson, N. A. (2007). A momentary assessment study of the relationship between affective and

adrenocortical stress responses in daily life. *Biological Psychology, 74*, 60–66. doi: 10.1016/J.Biopsycho.2006.07.002

Kahn, M., Sheppes, G., & Sadeh, A. (2013). Sleep and emotions: Bidirectional links and underlying mechanisms. *International Journal of Psychophysiology, 89*, 218–228. doi: 10.1016/J.Ijpsycho.2013.05.010

Klaperski, S., Seelig, H., & Fuchs, R. (2012). Physical activity as a stress buffer. *Zeitschrift für Sportpsychologie [Journal of Physical Activity in Psychology], 19*, 80–90. doi: 10.1026/1612-5010/A000061

Kraemer, H. C., & Blasey, C. M. (2004). Centring in regression analyses: A strategy to prevent errors in statistical inference. *International Journal of Methods in Psychiatric Research, 13*, 141–151. doi: 10.1002/Mpr.170

Lyubomirsky, S., King, L., & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin, 131*, 803–855. doi: 10.1037/0033-2909.131.6.803

Macht, M., & Dettmer, D. (2006). Everyday mood and emotions after eating a chocolate bar or an apple. *Appetite, 46*, 332–336. doi: 10.1016/J.Appet.2006.01.014

Mata, J., Hogan, C. L., Joormann, J., Waugh, C. E., & Gotlib, I. H. (2013). Acute exercise attenuates negative affect following repeated sad mood inductions in persons who have recovered from depression. *Journal of Abnormal Psychology, 122*, 45–50. doi: 10.1037/A0029881

Mata, J., Thompson, R. J., Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Gottlib, I. H. (2012). Walk on the bright side: Physical activity and affect in major depressive disorder. *Journal of Abnormal Psychology, 121*, 297–308. doi: 10.1037/a0023533

Minkel, J., Moreta, M., Muto, J., Htaik, O., Jones, C., Basner, M., & Dinges, D. (2014). Sleep deprivation potentiates HPA axis stress reactivity in healthy adults. *Health Psychology, 33*, 1430–1434. doi: 10.1037/A0034219

Moksnes, U. K., Moljord, I. E., Espnes, G. A., & Byrne, D. G. (2010). Leisure time physical activity does not moderate the relationship between stress and psychological functioning in Norwegian adolescents. *Mental Health and Physical Activity, 3*, 17–22. doi: 10.1016/j.mhpa.2009.12.002

Molenaar, P. C. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement, 2*, 201–218. doi: 10.1207/s15366359mea0204_1

Mroczek, D. K., & Almeida, D. M. (2004). The effect of daily stress, personality, and age on daily negative affect. *Journal of Personality, 72*, 355–378. doi: 10.1111/J.0022-3506.2004.00265.X

Muscatell, K. A., & Eisenberger, N. I. (2012). A social neuroscience perspective on stress and health. *Social and Personality Psychology Compass, 6*, 890–904. doi: 10.1111/j.1751-9004.2012.00467.x

Norris, R., Carroll, D., & Cochrane, R. (1992). The effects of physical-activity and exercise training on psychological stress and well-being in an adolescent population. *Journal of Psychosomatic Research, 36*, 55–65. doi: 10.1016/0022-3999(92)90114-H

O'Connor, D. B., Jones, F., Conner, M., McMillan, B., & Ferguson, E. (2008). Effects of daily hassles and eating style on eating behavior. *Health Psychology, 27*, S20–S31. doi: 10.1037/0278-6133.27.1(Suppl.).S20

O'hara, R. E., Armeli, S., Boynton, M., & Tennen, H. (2014). Emotional stress-reactivity and positive affect among college students: The role of depression history. *Emotion, 12*. doi: 10.1037/a0034217

Preacher, K. J., Curran, P. J., & Bauer, D. J. (2006). Computational tools for probing interactions in multiple linear regression, multilevel modeling, and latent curve analysis. *Journal of Educational and Behavioral Statistics, 31*, 437–448. doi: 10.3102/10769986031004437

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage Publications.

Rejeski, W. J., Thompson, A., Brubaker, P. H., & Miller, H. S. (1992). Acute exercise - buffering psychosocial stress responses in women. *Health Psychology, 11*, 355–362. doi: 10.1037//0278-6133.11.6.355

Riemann, D., & Backhaus, J. (1996). *Behandlung von Schlafstörungen [Treatment of sleep disorders]*. Weinheim, Germany: Beltz Psychologie-Verlag-Union.

Rimmele, U., Zellweger, B. C., Marti, B., Seiler, R., Mohiyeddini, C., Ehlert, U., & Heinrichs, M. (2007). Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. *Psychoneuroendocrinology, 32*, 627–635. doi: 10.1016/J.Psyneuen.2007.04.005

Roecke, C. (2006). *Intraindividual variability in positive and negative affect.* Doctoral dissertation, Freie Universität Berlin, Germany. Retrieved from http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002464

Roozendaal, B., McEwen, B. S., & Chattarji, S. (2009). Stress, memory and the amygdala. *Nature Reviews Neuroscience, 10*, 423–433. doi: 10.1038/Nrn2651

Roth, D. L., & Holmes, D. S. (1985). Influence of physical fitness in determining the impact of stressful life events on physical and psychologic health. *Psychosomatic Medicine, 47*, 164–173.

Roth, D. L., & Holmes, D. S. (1987). Influence of aerobic exercise training and relaxation training on physical and psychologic health following stressful life events. *Psychosomatic Medicine, 49*(4), 355–365.

Smyth, J., Ockenfels, M. C., Porter, L., Kirschbaum, C., Hellhammer, D. H., & Stone, A. A. (1998). Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. *Psychoneuroendocrinology, 23*, 353–370. doi: 10.1016/S0306-4530(98)00008-0

Steenhuis, I. (2009). Guilty or not? Feelings of guilt about food among college women. *Appetite, 52*, 531–534. doi: 10.1016/J.Appet.2008.12.004

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Pearson.

Thoits, P. A. (2010). Stress and health: Major findings and policy implications. *Journal of Health and Social Behavior, 51*, S41–S53. doi: 10.1177/0022146510383499

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070. doi: 10.1037/0022-3514.54.6.1063

Wrzus, C., Luong, G., Wagner, G. G., & Riediger, M. (2014). Can't get it out of my head: Age differences in affective responsiveness vary with preoccupation and elapsed time after daily hassles. *Emotion*. doi: 10.1037/emo0000019

Wrzus, C., Wagner, G. G., & Riediger, M. (2014). Feeling good when sleeping in? Day-to-day associations between sleep duration and affective well-being differ from youth to old age. *Emotion, 14*(3), 624–628.

Zschucke, E., Renneberg, B., Dimeo, F., Wustenberg, T., & Strohle, A. (2015). The stress-buffering effect of acute exercise: Evidence for HPA axis negative feedback. *Psychoneuroendocrinology, 51*, 414–425. doi: 10.1016/j.psyneuen.2014.10.019

Table 1

Sample Characteristics

	Study 1 (N = 292)	Study 2 (N = 304)
Gender (women %)	75.0%	64.1%
Age (*M, SD*)	20.7 (2.5)	21.4 (5.1)
Physical activity (*M, SD*)	368.1 (464.3)	422.5 (515.1)
Sleep quality (*M, SD*)	3.6 (1.0)	3.6 (1.0)
Snacking (*M, SD*)	2.2 (2.2)	2.3 (2.2)
Stress (*M, SD*)	0.6 (0.6)	1.1 (0.9)
Positive affect (*M, SD*)	4.9 (1.4)	4.9 (1.4)
Negative affect (*M, SD*)	2.3 (1.3)	2.2 (1.3)

Note: Sleep quality was rated on a 5-point Likert scale from 1 (*very bad*) to 5 (*very good*). Minutes of mild, moderate, and strenuous *physical activity* were converted into metabolic equivalents. In Study 1, *stress* was rated on a 5-point Likert scale from 1 (*little stress*) to 5 (*very stressful*) and in Study 2 on a 6-point Likert scale from 0 (*not experienced*) to 5 (*very stressful*). *Positive and negative affect* were rated on a 7-point Likert scale from 1 (*not at all*) to 7 (*extremely*).

Table 2

Results of the Multilevel Regression Analyses for Study 1 and Study 2

Outcome	Positive affect				Negative affect			
	Study 1		Study 2		Study 1		Study 2	
	B (*SE*)	95% CI	B (*SE*)	95% CI	B (*SE*)	95% CI	B (*SE*)	95% CI
Model 1								
Physical activity	0.57 (0.05)	[0.47, 0.66]*	0.65 (0.05)	[0.55, 0.75]*	-0.11 (0.02)	[-0.13, -0.08]*	-0.10 (0.02)	[-0.13, -0.07]*
Stress	-10.63 (0.61)	[-11.82, -9.45]*	-13.00 (0.57)	[-14.11, -11.85]*	3.80 (0.17)	[3.46, 4.13]*	4.80 (0.17)	[4.48, 5.13]*
Physical activity x Stress	0.54 (0.20)	[0.15, 0.93]*	0.36 (0.19)	[-0.01, 0.73]	-0.13 (0.06)	[-0.25, -0.01]*	-0.15 (0.06)	[-0.26, -0.04]*
Model 2								
Sleep quality	1.78 (0.11)	[1.56, 2.00]*	1.30 (0.11)	[1.09, 1.52]*	-0.54 (0.03)	[-0.61, -0.47]*	-0.37 (0.03)	[-0.43, -0.30]*
Stress	-9.48 (0.59)	[-10.64, -8.32]*	-12.13 (0.57)	[-13.25, -11.01]*	3.47 (0.17)	[3.14, 3.80]*	4.56 (0.17)	[4.23, 4.88]*
Sleep quality x Stress	1.46 (0.44)	[0.60, 2.31]*	0.91 (0.40)	[0.12, 1.70]*	-0.14 (0.13)	[-0.40, 0.13]	-0.33 (0.12)	[-0.57, -0.10]*
Model 3								
Snacking	0.57 (0.16)	[0.26, 0.88]*	0.46 (0.15)	[0.16, 0.75]*	-0.08 (0.05)	[-0.18, 0.01]	-0.01 (0.04)	[-0.10, 0.08]
Stress	-10.46 (0.61)	[-11.66, -9.27]*	-13.15 (0.57)	[-14.27, -12.02]*	3.77 (0.17)	[3.43, 4.11]*	4.83 (0.17)	[4.50, 5.16]*
Snacking x Stress	0.62 (0.62)	[-0.60, 1.84]	0.07 (0.54)	[-1.00, 1.13]	-0.16 (0.19)	[-0.53, 0.21]	0.07 (0.16)	[-0.25, 0.38]

Note. Estimates of the main effects can be interpreted as predictors were person-mean centerd. Positive and negative affect were multiplied by 10 in order to obtain more significant digits. *B* = unstardized regression coefficient; *95% CI* = lower and upper confidence interval*; SE* = standard error; * $p < .05$.

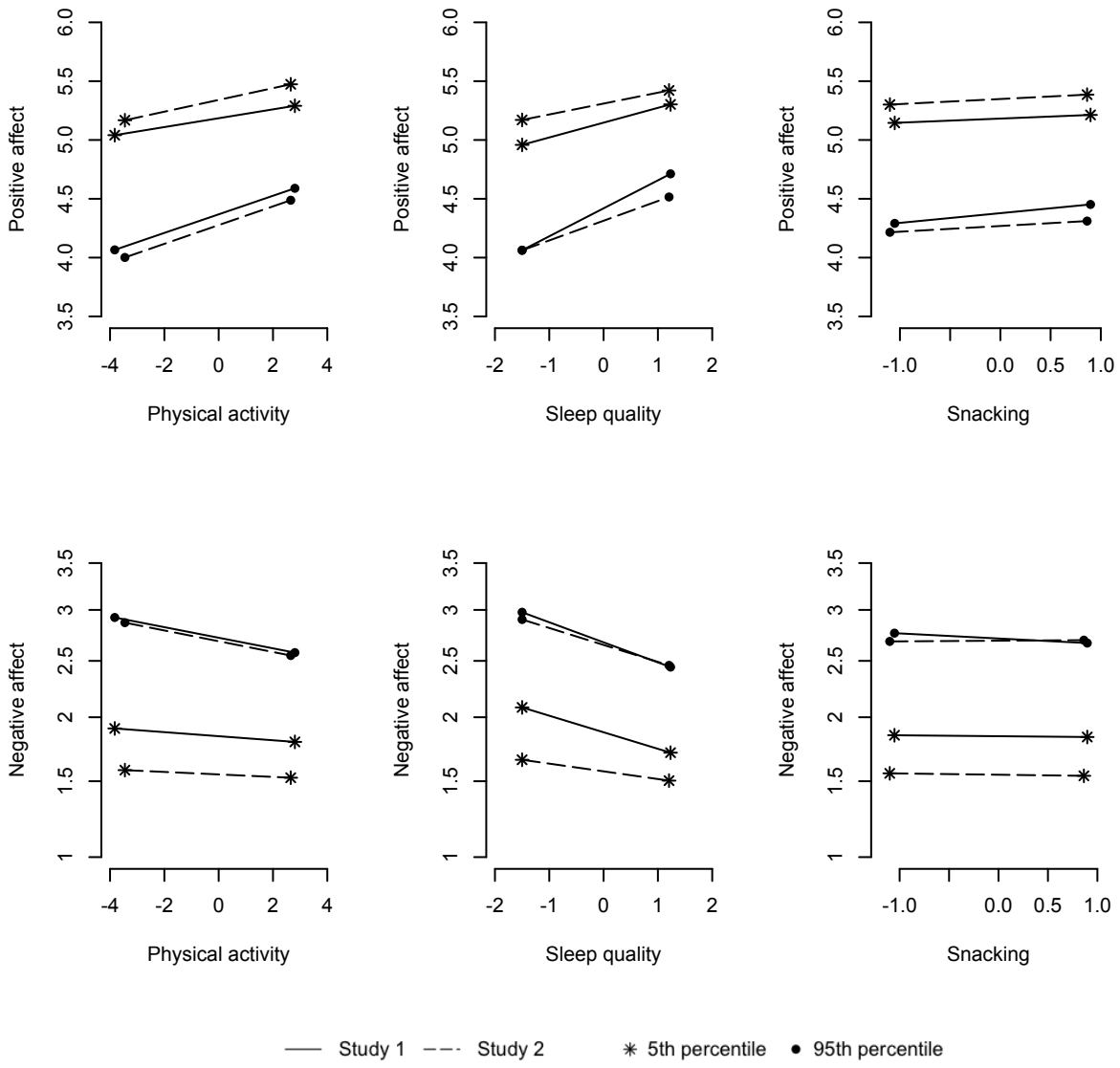

Figure 1: The interaction between daily health behaviors and daily stress in the prediction of daily positive and negative affect of Study 1 and Study 2. Values denote estimates from a multilevel model. Note that the moderator stress was continuously distributed and was only regrouped into two categories (5th and 95th percentile) in this figure for illustration purposes. The predictors physical activity, sleep quality, and snacking were person-mean centered. Since negative affect was transformed to approximate normal distribution, axes of negative affect were back-transformed to simplify the interpretation.