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NATURE EXTENDS FUTURE: THE MEDIATING ROLES OF AFFECT AND SUBJECTIVE VITALITY

A THESIS APPROVED FOR THE

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Abstract

Past research has shown that nature experiences can slow down the perception of temporal duration and shift time perspective from the past to the present and future. Little is known, however, about how nature would influence people's perception of future time left or future time perspective (FTP). In this research, I proposed that nature could expand people's FTP. Across four studies, I found consistent support for this hypothesis. In Study 1, a correlational analysis revealed that connectedness to nature was positively associated with FTP in both American and Chinese samples. In Studies 2 and 3, participants who viewed 14 photos of natural scenes reported more expansive FTP than those who watched 14 photos of urban scenes. Moreover, both positive (vs. negative) affect (Study 2) and subjective vitality (Study 3) mediated the effect of nature on FTP. In Study 4, I tested the link between nature and FTP at the macro level by analyzing large-scale data on 1686 U.S. counties (N = 772, 956), demonstrating that people living in greener counties believed they would live longer and perceived themselves as having a longer future. Together, these findings indicate that nature can broaden people's subjective sense of time availability.

Keywords: Nature, future time perspective, positive and negative affect, subjective vitality

Introduction

Those who contemplate the beauty of the earth find reserves of strength that will endure as long as life lasts. There is something infinitely healing in the repeated refrains of nature—the assurance that dawn comes after night, and spring after winter.

-----Rachel Carson, *Silent Spring* (1962)

One of nature's wonders is that it always tells us about its past silently. We observe a sapling into a towering tree and trace its history through the rings of its trunk. We watch a river flowing by and a flock of birds flying across the sky, and we sense the paths they have traveled. However, nature does more than connect us to the past—it also invites us to look ahead. We imagine the fruits the tree will bear, the distant lands the river will reach, and the destinations the birds will find. In this way, nature shifts our focus from the present to the future, inspiring us to reflect not only on the future of the natural world but also on our own future.

Indeed, recent research has supported this idea, demonstrating that nature can shift time perspectives, making people care more about the future than the past and present (Berry et al., 2015, 2019; Kao et al., 2019; Michels et al, 2022; Van der Wal et al., 2013). Yet, an intriguing question that remains unknown is whether nature can influence people's perception about their remaining future time, or future time perspective (FTP). FTP can profoundly shapes people's present behaviors and decisions, including goal setting, motivations, achievements, social relationships, and personality change (e.g., Allemand et al., 2012; Brothers et al., 2016; Cate & John, 2007; De Volder & Lens, 1982; Hill et al., 2022; Löckenhoff & Carstensen, 2004), across multiple life domains (Liao & Carstensen, 2018). Notably, an expansive FTP was associated with higher well-being, lower levels of depression and loneliness, better retirement adjustment,

and more successful aging compared to a limited FTP (Bergman & Segel-Karpas, 2018; Coudin & Lima, 2011; Kozik et al., 2015; Soylu & Ozekes, 2023; Xia et al., 2024). In this thesis, I proposed that nature would extend people's FTP, with positive (vs. negative) affect and subjective vitality as potential mediators. I conducted a series of studies to test these possibilities.

In the sections below, I will first outline the research background, including the psychology of nature and the psychology of FT. Then I will explain why nature could expand FTP, including past relevant research and possible underlying mechanisms (i.e. positive (vs. negative) affect, subjective vitality). Finally, I will propose the research plan.

Research Background

The Psychology of Nature

Nature has nurtured human beings for millions of years. It not only provides essential resources for survival but also shapes human mind and behavior. Over the past decades, a large body of research have been devoted to the impacts of nature on human psychology. Below, I will first illustrate how nature has been operationalized in psychological research. Then I will review the main theories about the psychology of nature and its benefits for human.

What is Nature?

Nature is a broad and multifaceted concept that can be understood from various perspectives. To date, there is no universally accepted definition about nature. In this thesis, I adopt Russell et al.'s (2013) definition. According to Russell et al. (2013), nature "encompasses both living and nonliving components of ecosystems, including human-modified environments but excluding nonliving human-built environments". Obviously, nature includes both wild natural environments (e.g., forests, mountains, and lakes) and human-built or manicured natural

environments (e.g., urban parks and street trees). Ecosystems, in this context, can encompass a wide range of elements, including mundane natural components like trees and lakes, and more dynamic or extreme phenomena such as hurricane, winter scenery, or even vicious animals. Following the majority of studies on the effects of nature (e.g., Baxter & Pelletier, 2019; Maller et al., 2006), this thesis primarily focuses on mundane, nonthreatening, and pleasant nature. Commonly studied natural elements include forests, parks, gardens, and lakes. Notably, in past research, the terms *nature*, *natural environment*, and *natural landscapes* are usually interchangeably used and typically contrasted with urban environments (e.g., buildings, streets, malls).

In addition to physical nature, the existing research has also examined the influences of psychological connection with nature. Just like humans have a fundamental need for belonging to social groups, they also have the need for belonging to the natural world. However, researchers have conceptualized psychological connection to nature in various ways. Early philosophers introduced the concept of *ecological self* to describe how humans construct their identity with ecological environments (Naess, 1973). Schultz (2002) extended on this idea by proposing *inclusion with nature*, consisting of three components: connectedness (i.e., integrating nature with one's cognitive representation of self), caring for nature (i.e., feeling of closeness and affection with nature), and behavioral commitment (i.e., acting to protect nature). Similarly, *nature relatedness* divides the human-nature relationship into three components: personal connection to nature, nature-related worldviews, and physical familiarity with nature (Nisbet et al., 2009). Despite these multi-dimensional constructs, some researchers conceptualize a unidimensional *connectedness to nature*, describing an experiential and affective sense of oneness with the natural world (Mayer & Frantz, 2004). Although these constructs have a lot of

overlap in conceptualization, they have been widely used in existing literature and have been shown to strongly converge in measuring individuals' trait level connection to nature (Restall & Conrad, 2015).

Overall, the existing research has typically approached nature in two ways: either a kind of physical environment or a kind of psychological connections with it. The present thesis follows these two operationalizations, investigating both the causal impacts of natural environments and the associations of nature connection with related outcomes.

Theories about Nature

Several theories have emerged to describe and explain how nature affects humans. Among those theories, the most widely recognized ones include the biophilia hypothesis, the stress-reduction theory, and the attention restoration theory.

Biophilia Hypothesis The biophilia hypothesis assumes that humans have an innate affinity for the natural world and other living beings, which is rooted in our evolutionary adaptation to natural environments (Kellert & Wilson, 1995; Wilson, 1984). This adaptation provided a survival advantage, leading people to prefer natural environments where they could thrive. Although the biophilia hypothesis is widely spread, it has received limited direct empirical support due to its difficulty in being falsified. For example, some research using implicit tests has found participants exhibited an automatic tendency to approach nature while avoiding build environments (Schiebel et al., 2022). However, substantial indirect evidence for the hypothesis came from research on the effects of nature exposure. Studies have shown that satisfying people's needs to affiliate with nature---through direct or virtual exposure to nature---can enhance human health and well-being (e.g., Gaekwad et al., 2022; Grinde & Patil, 2009). Likewise, an analysis of social media photographs across 185 counties found that people were

more likely to capture natural scenery during enjoyable activities than in their daily routines, suggesting an association between nature and life's most pleasurable moments (Chang et al., 2020).

Stress-Reduction Theory Unlike the biophilia hypothesis, the stress-reduction theory (SRT; Ulrich et al., 1991) emphasizes the beneficial effects of nature on human. It suggests that urban environments bring humans a lot of stress while exposure to nature helps alleviate it. According to SRT, humans has evolved in natural environments over time, developing an innate ability to automatically and quickly respond to natural stimuli in ways that promote restorative experiences to maximize their chances of survival (Kaplan & Berman, 2010; Ulrich, 2023). As a result, the theory posits that contact with non-threatening natural environments can increase positive affect and reduce negative affect and psychological stress.

Attention Restoration Theory Similar to SRT, the attention restoration theory (ART; Kaplan, 1995) also highlights nature's restorative effects but focuses on cognitive benefits. It suggests that urban environments are filled with alert stimuli that requires people's directed attention in a top-down manner (e.g., avoiding traffic, finishing work, identifying misinformation). In contrast, natural environments are filled with relaxing stimuli that requires only involuntary attention in a bottom-up manner (e.g., birdsong, green views). Therefore, ART posits that exposure to nature can recover directed attention and encourage effortless brain functions, thereby alleviating mental fatigue and restoring depleted energy (Hartig, 2021; Ohly et al., 2016).

Empirical research has largely supported these theories from various perspectives, especially for SRT and ART. In the following sections, I will review evidence demonstrating

nature's benefits for human health, including physical, mental, and social health, as well as cognitive performance.

Health Benefits of Nature

Physical Health While urbanization has improved the efficiency of daily life, it has also introduced many threats to human health, such as climate change, pollution, and a high risk of obesity and diabetes (Flies et al., 2019). The rising prevalence of these "urban-associated diseases" has prompted a renewed interest in nature involvement, as it can purify environments and encourage people healthier lifestyles, such as fostering physical activities. As a result, contact with nature has been shown to have substantial benefits for physical health in existing research (e.g., Bowler et al., 2010; Triguero-Mas et al., 2015; White et al., 2019). For example, multiple meta-analyses have consistently found that greater residential greenness was associated with better birth and mortality outcomes, such as lower all-cause mortality (Gascon et al., 2016; Rojas-Rueda et al., 2019), a reduced risk of preterm birth, and higher birth weights (Akaraci et al., 2020; Hu et al., 2021). More specifically, individuals living in greener areas tend to exhibit lower levels of salivary cortisol, reduced heart rates, and lower blood pressure (Twohig-Bennett & Jones, 2018) as well as a decreased likelihood of developing incident cardiovascular diseases, hypertension, obesity, and diabetes (Astell-Burt & Feng, 2020; Halonen et al., 2014). Studies on human and animals also suggested that exposure to nature enhanced immune system functioning, as indicated by improvements in immunological health parameters (Andersen et al., 2021). Apart from these physiological benefits, greenspace exposure can also improve sleep quality and quantity, according to findings in cross-sectional and intervention studies (Shin et al., 2020). At the trait level, higher nature relatedness was associated with lower somatic anxiety, fewer

symptoms of depression, anxiety, stress, and better overall health (Dean et al., 2018; Lawton et al., 2017).

Mental Health As mental health is closely linked to physical health, nature also yields restorative benefits for our mental health. First, in line with SRT, previous research has demonstrated that exposure to nature can enhance mood, satisfy psychological needs, and reduce the risk of mental disorders. For example, experiencing nature has been shown to increase positive emotions (Hong et al., 2019). This effect can be mediated by an increased sense of connectedness to nature (Mayer et al., 2009). Physical activity in natural settings produced more consistent emotional benefits compared to physical activity in urban environments (Mitchell, 2013; Pasanen et al., 2014). The positive effects of nature on well-being can also be long-term, as childhood exposure to residential greenspace has been linked to better mental health in adulthood (Li et al., 2022). Beyond enhancing positive emotions, some extraordinary natural experiences can elicit self-transcendent emotions (Neill et al.,2019), such as awe (Anderson et al., 2018; Ballew & Omoto, 2018). At the same time, nature helps mitigate negative emotions and serves as a buffer against negative states, such as loneliness and stress (Astell-Burt et al., 2022; Tyrväinen et al., 2014). It has also been associated with a reduced risk of depression, particularly among older adults and people of low socio-economic status (Helbich et al., 2019; Marselle et al., 2020). Moreover, residents of greener areas had lower odds of developing common mental health disorders (Thompson et al., 2021). Similarly, research found that children in economically disadvantaged neighborhoods with greater access to greenspace were less likely to require medication for attention deficit hyperactivity disorder (ADHD; de Vries & Verheij, 2022).

Second, in addition to emotional benefits, nature enhances psychological functioning. A lot of research has demonstrated that exposure to nature (e.g., exercise in natural environments) can boost self-esteem across all age groups, including children, adults, and the elderly (Barton et al., 2012; Barton & Pretty, 2010; Heród et al., 2024). This may be because that nature promotes positive emotions and reduce rumination, a maladaptive pattern of self-referential thoughts (Bratman, Hamilton, et al., 2015). As a result, people who engage with nature tend to feel good about themselves and develop greater self-acceptance and self-worth. Furthermore, the effects of nature on self-esteem also contributed to increasing body appreciation and maintaining a positive body image (Swami et al., 2016, 2018, 2019). Recent research also highlighted that contact with nature promote autonomy, personal growth, life meaning, and authenticity (Pritchard et al., 2020; Yang et al., 2024). Trait level connectedness to nature was also positively associated with well-being, trait mindfulness, autonomy, purpose in life/meaning, and self-acceptance (Capaldi et al., 2014; Cervinka et al., 2012; Howell et al., 2011; Martin et al., 2020; Pritchard et al., 2020; Schutte & Malouff, 2018).

Overall, nature is widely recognized as a source of both hedonic and eudaimonic well-being, providing both short- and long-tern benefits (Capaldi et al., 2015; Cleary et al., 2017; Irvine et al., 2013; Li et al., 2022).

Social Health In addition to nature's positive impacts on physical health and mental health, there is growing interest in nature's role in enhancing individuals' social health. Social health refers to the ability to form and maintain relationships and well-being from social connection and community engagement (Keyes, 1998). Existing research has shown that exposure to natural environments can improve social health in various ways (Arbuthnott, 2023). First, natural environments usually offer enjoyable settings for neighbourly interaction and

recreation (Liu et al., 2020). People who live near nature thus engaged more with neighbors and have higher level of nature relatedness, formed stronger social ties with neighbors (Kaźmierczak, 2013), reported a greater sense of community belonging (Rugel et al., 2019), and higher levels of social cohesion (Jennings & Bamkole, 2019; Oh et al., 2022). Second, immersion in nature lowered self-focused orientations (Weinstein et al., 2009) and increased other-focused social goals. For example, spending time in nature has been found to promote cooperation (Zelenski et al., 2015), helping behavior (Guéguen & Stefan, 2016) and charitable donations (Castelo et al., 2021). Nature exposure also elicited self-transcendent emotions such as awe (Ballew & Omoto, 2018; Mei et al., 2024), which further enhanced generosity and prosocial behavior (Castelo et al., 2021; Goldy & Piff, 2020; Piff et al., 2015). Third, exposure to nature was linked to reduced antisocial behavior. Residents living in greener spaces engaged in less violence and criminal activity than those in less green areas (Kuo & Sullivan, 2001a, 2001b; Sanciangco et al., 2022). Viewing nature pictures also reduced aggression, particularly among ego depleted persons or ostracized persons (Poon et al., 2016; Wang et al., 2018).

Cognitive Benefits of Nature

According to ART, nature benefits humans by improving cognitive functions. Supporting evidence has demonstrated that immersion in nature helps restore directed attentional capacity and recover from cognitive fatigue (Berman et al., 2008; Berto, 2005; Bratman et al., 2012; Felsten, 2009; Kasap et al., 2021). Research also showed that exposure to nature increased working memory performance (Bratman, Hamilton, et al., 2015; Schertz & Berman, 2019), impulse inhibition (Taylor et al., 2002), and cognitive flexibility (Stevenson et al., 2018). Apart from bottom-up stimuli from nature, people's top-down attribution of the source of ambiguous sound to nature (vs. urban) also led to higher happiness and relaxing experience, and lower

brain's alpha activity (Koivisto et al., 2022). People who felt more closely connected to nature exhibited more innovative and holistic thinking (Leong et al., 2014).

Experimental and intervention research on schoolchildren and adolescents have revealed the benefits of natural environments on their cognitive development (e.g., Dadvand et al., 2015; Vella-Brodrick & Gilowska, 2022). Specifically, higher daily exposure to woodland was associated with improved executive function and enhanced working memory performance among adolescents (Dadvand et al., 2015; Maes et al., 2021). Biophilic learning environments increased more attentional performance in pupils than conventional learning spaces (Barbiero et al., 2021). Moreover, evidence from EEG studies also demonstrated that viewing living plants improved the concentration of elementary students (Oh et al., 2019).

In summary, substantial studies consistently indicated that nature provides generous benefits for physical strength, mental health, social tendency, and cognitive functioning. Additionally, emerging research has suggested that nature may influence time perception, including the perception of temporal duration and time perspective (Berry et al., 2015; Davydenko & Peetz, 2017; Van der Wal et al., 2013). However, no research has examined nature's potential impacts on individuals' perception of future time. I argue that exposure to nature may increase people's sense of future time availability, or FTP. In the following section, I will review the literature related to FTP and propose my hypotheses.

The Psychology of FTP

FTP has been conceptualized as perceived remaining future time on a uni-dimensional continuum (Carstensen et al., 1999; Lang & Carstensen, 2002): Individuals may perceive their future time as expansive and open-ended (i.e., having a lot of time) versus as limited and short (i.e., time is running out). Up to date, a large body of research has demonstrated the impacts of

FTP on various psychological processes (e.g., Allemand et al., 2012; Cate & John, 2007; Löckenhoff & Carstensen, 2004) and, at the meantime, revealed diverse correlated factors that influence FTP (e.g., Kooij et al., 2018; Lang & Carstensen, 2002).

The Impacts of FTP

The impacts of FTP on individuals are most notably explained by socioemotional selectivity theory (Carstensen et al., 2003; Carstensen et al., 1999). It posits that individuals' selection and pursuit of life goals are a function of FTP. When people perceive their future as expansive, they tend to prioritize knowledge-based goals, referring to acquisition of knowledge or information for future and finding one's role in the society. In contrast, when future time is perceived limited, people tend to prioritize emotion-based goals, which encompass the desire to seek emotionally meaningful benefits and emotional intimacy (Carstensen et al., 2003).

Such a shift in goals influences social preference, emotion regulation, cognitive processing, and personality change. Research has found that people with an open-ended FTP prioritized social acceptance and autonomy in social relationships and maintained larger social networks that include a variety of acquaintances and friends. In contrast, those with a limited FTP prioritized emotional regulation and generativity in social relationships, and preferred smaller and intimate social networks consisting primarily of family and close friends (e.g., Fung et al., 1999; Lang & Carstensen, 2002). A limited FTP also leads to better emotional balance and more adaptive emotion regulation strategies, helping maximize positive emotions and minimize negative emotions compared to an open-ended perspective (Carstensen et al., 2003; Löckenhoff & Carstensen, 2004; Sims et al., 2015). In terms of cognitive processing, people with a limited FTP showed an attention bias in favor of positive over negative stimuli, regardless of age (Zsoldos & Hot, 2024). Older adults with a limited FTP also performed worse in recognition and

recall memory for negative images than young adults with a more open-ended perspective (Charles et al., 2003). Additionally, among adults who are experiencing retirement transition, broader FTP predicted increased openness and reduced neuroticism over time (Hill et al., 2022).

The Factors that May Influence FTP

Although much is known about the impacts of FTP, less attention has been given to the factors that may influence it. Two primary factors studied in research are age and health status. As people age or experience worsening health conditions (e.g., HIV negative vs. HIV positive, asymptomatic vs. HIV positive, symptomatic), they are likely to perceive greater limitation in the future and feel less future time left (Carstensen & Fredrickson, 1998; Kooij & Van De Vorder, 2011; Lang & Carstensen, 2002). Other demographic factors, including gender, education level, and income, also play a role. Research suggested that females and individuals with higher income or education levels generally perceive a broader FTP than males and those with lower income or education levels (Kooij et al., 2018; Padawer et al., 2007). Additionally, FTP can be constrained for a specific situation that represents an ending in life. For example, research found that geographic relocation, college graduation, retirement, the last day of a year, and sociopolitical ending (e.g., the handover of Hong Kong from the UK to China) foreshortened FTP (Carstensen, 2006; Hepper et al., 2021; Löckenhoff & Carstensen, 2004; Xia et al., 2024; Zhang & Fung, 2009). Other studies suggested that exposure to negative aging stereotypes also led to reduced FTP among older adults (Barber & Tan, 2018).

Nature and FTP

Despite the primary focus of existing literature on factors that limit FTP, far less is known about what may broaden it. Moreover, research has revealed that an expansive FTP was associated with higher well-being, lower levels of depression and loneliness, better retirement

adjustment, and more successful aging compared to a limited FTP (Bergman & Segel-Karpas, 2018; Coudin & Lima, 2011; Kozik et al., 2015; Soylu & Ozekes, 2023; Xia et al., 2024). Thus, identifying factors that could expand FTP is crucial for promoting psychological health. To address this gap, the present study introduces an environmental factor---exposure to nature---as a potential way expanding FTP. Below, I reviewed how exposure to nature may shape individuals' perceptions of future time and propose my hypotheses.

The Potential Link between Nature and FTP

The potential link between nature and FTP may arise from the effects of nature on time perception. Existing research has primarily focused on two major lines. The first line of research suggested that exposure to nature can slow down individuals' subjective temporal perception. Studies have found that participants tend to overestimate the duration of experiences in natural settings compared to their actual duration, an effect not observed in urban environments (Berry et al., 2015; Davydenko & Peetz, 2017). Additionally, it also took longer for participants to estimate the passage of one minute when exposed to nature versus urban settings (Davydenko & Peetz, 2017). This overestimation of time duration may be due to an increased awareness of time flow by nature (Ehret et al., 2020). As people become more attuned to the flow of time, they will feel time passing slower (Zakay & Block, 1995).

Another line of research indicated that nature experiences appear to shift time perspectives. Exposure to nature shifted attention away from the past and toward the present and future, particularly fostering greater emphasis on future rewards over immediate rewards (Van der Wal et al., 2013). Research has shown that viewing pictures of nature and walking in a natural setting reduced impulsive decision-making and delay discounting, thereby promoting healthier long-term choices, such as lower sugar consumption, a higher implicit vegetable

preference but lower sweet and fat snack preference (Berry et al., 2019; Kao et al., 2019; Michels et al, 2022; Repke et al., 2018). These findings suggest that exposure to nature may induce future-oriented thinking and long-term goal setting. I therefore argue that when people are exposed to natural environments, compared to urban environments, they are more likely to think about their future and take a longer-term view of their future, manifested as having a broader perception of future time. I posit that nature involvement is linked to, or extend FTP.

As to the mechanism underlying the link between nature and FTP, I examined two potential mediators: positive (vs. negative) affect, and subjective vitality. I argue that exposure to nature may extend FTP by increasing positive but decreasing negative affect, as well as fostering subjective vitality.

The Potential Mechanism: Positive (vs. Negative) Affect

It is well-established that exposure to nature, both real and virtual contact, raises positive affect (e.g., pleasant, happy, contented) and decreases negative affect (e.g., bad, unpleasant, angry; e.g., Beute & De Kort, 2014; Bratman, Daily, et al., 2015; Li et al., 2018; McMahan & Estes, 2015; White et al., 2013, 2014, 2017). Moreover, these affective benefits of nature appear to be culturally universal, supported by both behavioral and physiological evidence across West and East (Bratman et al., 2021).

On the other hand, positive (vs. negative) affect may extend FTP. This assumption is derived from the broaden-and-build theory. It posits that positive affect, relative to negative affect can broaden people's thought-action repertoire, demonstrated by broadened attentional, perceptional, cognitive, and behavorial scopes, and further build personal sources for enduring growth and survival (Fredrickson, 2001, 2013). For examplev, research found that positive affect can increase creativity and attential flexibility, fuel resilience, and stimulate a desire to acquire

skills and social support (Fredrickson, 1998; Isen et al., 1987; Tugade & Fredrickson, 2004). The broadening effect of positive affect also occurs in future outlooks. Positive emotions promoted forward looking, cognitive flexibility, and high-level thinking, while also reducing delayed discount (Isen, 2007; Pyone & Isen, 2011). In contrast, feeling negative emotions led to pessimistic views about the future (Marroquín et al., 2016). According to this theory, positive (vs. negative) affect may also broaden individuals' perceptions about future and thereby extend FTP. Supporting evidence showed that FTP was positively associated with positive affect and negatively associated with negative affect (Allemand et al., 2012; Hicks et al., 2012; Katana et al., 2020; Sirois et al. 2014).

By integrating the established effect of nature on affect with the link between affect and FTP, I argue that positive and negative affect may mediate the effect of nature on FTP.

The Potential Mechanism: Subjective Vitality

The second potential mechanism for the extending effect of nature on FTP may be subjective vitality. Subjective vitality is defined as one's experience of energy and aliveness, providing the drive and power to organize and initiate action (Ryan & Frederick, 1997). It is distinct from general physiological arousal or heightened emotional states such as anger or anxiety. Because unlike energy and arousal per se, subjective vitality arises from subjective control of self and optimal functioning, and it is able to be directed toward goal achievement (Lavrusheva, 2020; Ryan & Frederick, 1997).

Subjective vitality is influenced by both somatic and psychological factors. Somatic discomfort (e.g., feeling pain, being sick) and psychological distress (e.g., stress, depression, low self-esteem) can diminish one's felt energy available to the self. Additionally, subjective vitality was also grounded in the framework of Self-Determination Theory, which constructs the

importance of autonomy, competence, and relatedness in fostering well-being (Deci & Ryan, 2012). Research has demonstrated that subjective vitality was closely associated with self-actualization, self-determination, and self-esteem (Kasser & Ryan, 1999). When people's basic psychological needs such as autonomy, competence, and relatedness are met, their subjective vitality increases, whereas activities that deplete these needs will drain subjective vitality (Ryan & Deci, 2008).

In addition to internal factors, subjective vitality was also influenced by external factors. Social or autonomy support from close others (Carmeli et al., 2021; Muraven et al., 2008), daytime light exposure (Smolders et al., 2013; Smolders & de Kort, 2014), and even the day of the week (Ryan et al., 2010) have been shown to affect individuals' feelings of energy and aliveness. Another increasing body of research suggested that natural environments play a crucial role in enhancing subjective vitality. Spending more time in green spaces, or feeling more closely connected to nature was positively associated with higher level of mental health and vitality (Van den Berg et al., 2016; Zelenski & Nisbet, 2014). Walking outdoors and viewing slides depicting natural scenes led to higher subjective vitality than walking indoors or viewing slides of man-build scenes (Ryan et al., 2010). Moreover, research using virtual reality has also showed that exposure to various natural environments (e.g., a forest, a natural park, a lacustrine environment, and an arctic environment) enhanced vitality (Mattila et al., 2020; Theodorou et al., 2023). The vitalizing effect of nature is in line with the Attention Restoration Theory, supporting that nature provides restorative experiences by recovering energy that are depleted in everyday life (Ohly et al., 2016).

Subjective vitality also shows essential impacts on humans. Feeling vital and alive is an essential part of psychological well-being and serves as a protective factor for both physical and

mental health. Research found that subjective vitality may reduce the risk of cardiovascular disease (Kubzansky & Thurston, 2007; Richman et al., 2009) and the rates of disability and mortality (Penninx et al., 2000), and increase happiness (Akın, 2012; Uysal et al., 2014). Additionally, vitality has been linked to enhanced creativity (Kark & Carmeli, 2009) and reduced rumination (Arslan et al., 2022). College students who proactively managed vitality reported increased goal attainment, meaning in life, further promoting psychological well-being (Ren et al., 2024; Zhang, Zheng, et al., 2024).

Despite the benefits of subjective vitality, its relationship with FTP has received less attention. Some research suggested that vitality was positively related to a future-oriented mindset (Hirsch et al., 2015). Following this, I argue that subjective vitality may be positively associated with FTP. I propose this for two reasons. First, the feeling of vitality is rooted in a healthy somatic and mental condition, which is also essential for an expansive FTP. Individuals who feel less energetic often experience some physical or psychological discomfort. In this case, they are less likely to think and plan for the long term, but instead more likely to strive to recover energy in the short term. In contrast, those who feel vital and energized are more motivated to engage in long-term planning and goal setting, contributing to a broader FTP.

Second, as stated previously, subjective vitality is closely tied to personal control, autonomy, and growth (Ryan & Frederick, 1997). Autonomy, in particular, plays a significant role in shaping FTP. Feeling psychological freedom and control of oneself may foster hope and maximize expectations for a long future and more opportunities, thereby extending FTP. Supporting evidence suggested positive associations between autonomy and FTP (Baldensperger et al., 2018). Moreover, adolescents who received more autonomy support from parents exhibited greater FTP (Wang et al., 2022). Together, I argue that subjective vitality may extend

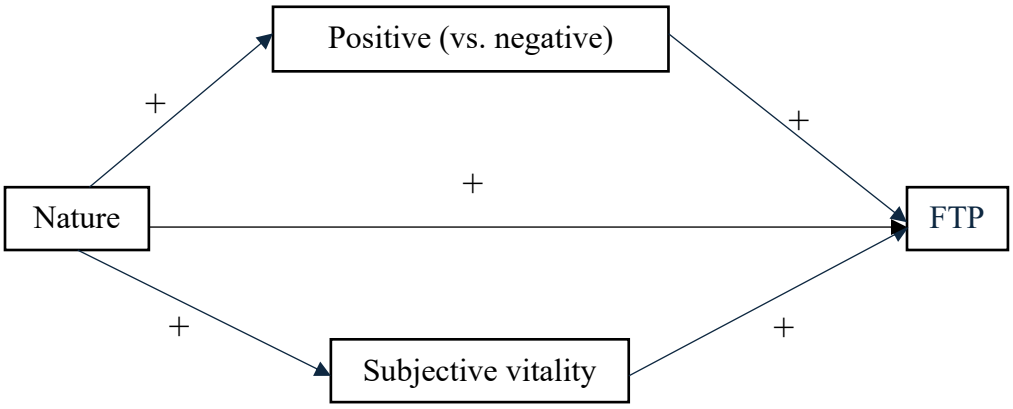
one's FTP. Considering the relationships of subjective vitality with nature and FTP, I posit that subjective vitality may mediate the link between nature and FTP.

Research Overview and Hypotheses

Extensive research has examined the psychological benefits of exposure to nature. However, its impacts on FTP remains unexplored. The present project extends the literature by proposing a new effect of nature experiences on time perspective toward future, as well as its underlying mechanism. I hypothesized that nature involvement would extend FTP, that is making people feel more time available in the future. I also tested two potential mediators that may explain the above effect. First, it is well-established that exposure to nature may increase positive affect and decrease negative affect. I argue that this emotional shift may then foster expansive FTP. In other words, positive (vs. negative) affect would mediate the effect of nature on FTP, as hypothesized. Second, exposure to nature can increase subjective vitality, the feeling of aliveness and energy to fully function. This energy available to people's inner self may be utilized to think further into future and expand FTP. I thus hypothesized that subjective vitality would mediate the effect of nature on FTP. Figure 1 displays the theoretical framework. Exploring the link between nature and FTP and its mechanisms will contribute to the understanding of how natural environments shape future outlooks and incorporate life-span development into nature's benefits framework. The project will also advance practical implications in urban planning and individual well-being.

Figure 1

The Theoretical Framework in the Present Research



I conducted four studies to test our hypotheses. First, to test the link between nature and FTP, I applied two operationalization of nature as I reviewed before. Specifically, in Study 1, I measured nature as individuals' trait-level connectedness to nature and examined its correlational relationship with FTP. To enhance generalizability of the findings, I surveyed both Western (e.g., American) and East Asian (e.g., Chinese) samples. In Studies 2 and 3, I operationalized nature as the physical environment and examined the causal effect of exposure to nature on FTP. Besides, I tested two plausible mechanisms underlying the above link: the mediating roles of positive (vs. negative) affect and subjective vitality in Studies 2 and 3, respectively. Finally, in Study 4, I tested whether the link between nature and FTP established at the individual level can be generalized at the county level by analyzing large-scale data from Project Implicit. This study examined the association between environmental greenspace and residents' FTP at the U.S. County level. All materials used in the present thesis are in the Appendix.

Study 1: Nature and FTP: A Correlational Study at the Individual Level

In Study 1, I aimed to test whether individuals' connectedness to nature was positively correlated with FTP and whether this link is culturally invariant in both American and Chinese samples.

Methods

Participants

Sample 1 A total of 719 students from the University of Oklahoma completed the survey in the prescreening study. I excluded 4 participants who didn't finish the survey. Our final sample size reached 715 (74.5% females, M_{age} = 18.49, *SD* = 1.20).

Sample 2 I recruited a total of 200 participants on Credamo, a Chinese data collection platform similar to Prolific. I excluded one participant for not completing the survey, leaving a sample of 199 participants (60.2% females, M_{age} = 31.27, *SD* = 8.45).

Materials

Nature connectedness was measured with the 14-item Connectedness to Nature Scale (Mayer & Frantz, 2004). Participants rated the extent to which they felt a part of nature on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*). Sample items included "I often feel a sense of oneness with the natural world around me" and "I think of the natural world as a community to which I belong" ($\alpha = .84, .88$). Then I assessed participants' FTP with the 10-item Future Time Perspective Scale (Carstensen & Lang, 1996; Fung et al., 2001). Sample items included "Most of my life lies ahead of me" and "My future seems infinite to me" (1 = *very untrue*, 7 = *very true*; $\alpha = .86, .84$). A higher score indicated that participants vieId their FTP as more expansive. Finally, participants will report their age and gender. Materials for Study 1 are available in Appendix A.

Results

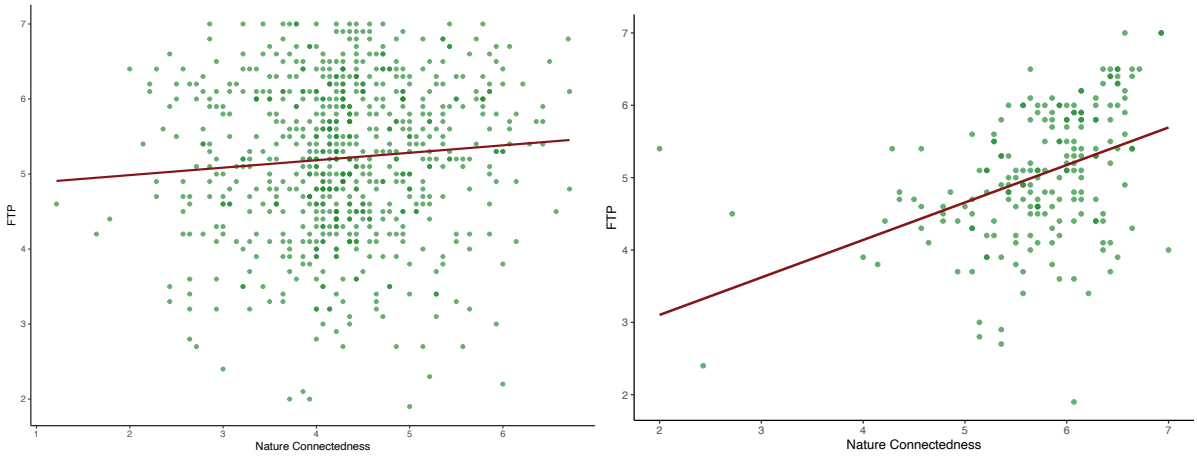
In both American and Chinese samples, regression analysis suggested that nature connectedness positively predicted FTP, $b_{sample1} = .09$, $t = 2.29$, $p = .02$, 95% CI [.01, .16]; $b_{sample2} = .52$, $t = 6.28$, $p < .001$, 95% CI [.36, .68] (see Figure 2). The results remained the same after controlling participants' age and gender, $b_{sample1} = .09$, $t = 2.45$, $p = .01$, 95% CI [.02, .17]; $b_{sample2} = .55$, $t = 6.38$, $p < .001$, $p < .001$, 95% CI [.38, .71].

Discussion

Together, two correlational analyses supported the hypothesis that connectedness to nature is positively linked to FTP. Moreover, this link exists across American and Chinese cultures. Next, I conducted Study 2 to examine the causal effect of exposure to nature on FTP, as well as the mediating role of positive (vs. negative) affect.

Figure 2

Nature Connectedness Positively Predicted FTP in Both American (Left) and Chinese (Right) Sample in Study 1



Study 2: Nature and FTP: An Experimental Study Testing the Mediating Role of Positive (vs. Negative) Affect

Method

Participants

Our main goal of Study 2 was to examine the causal effect of nature on FTP. A prior power analysis with G*Power 3.1 suggested a required sample of 352 participants to reach power of .80 at a low to medium effect size of $d = .30$ (Yang et al., 2024) and $\alpha = .05$. Since this study was conducted on Qualtrics and distributed by SONA, I recruited 400 participants to accommodate potential noises associated with online data collection. They were undergraduate students from the University of Oklahoma and compensated course credits for participation. I excluded 1 participant who didn't complete the survey, 48 participants who finished the survey over 3 median absolute deviation (i.e., 33 mins, the median duration was 15 mins) and 1 participant with extremely limited FTP (lower than 3 SD). Our final sample size reached 350 (75.1% females, $M_{age} = 18.49$, $SD = 1.20$).

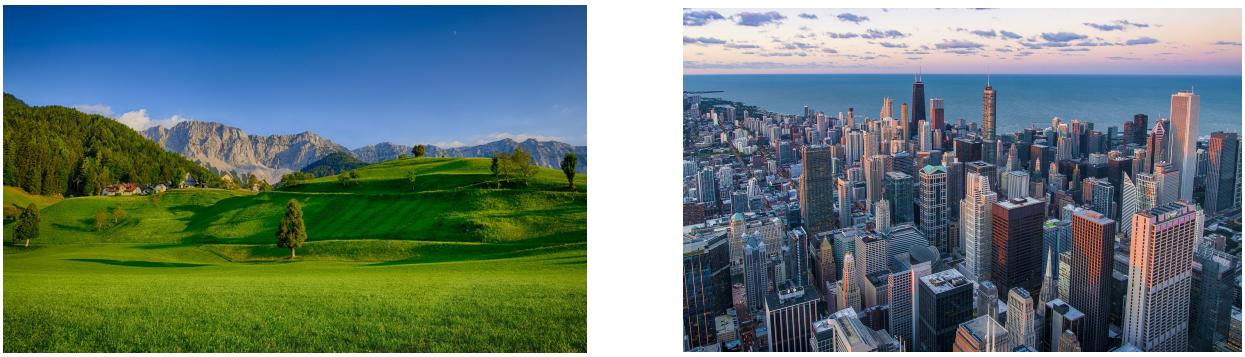
Procedures

To test the causal effect of nature, I used a completely randomized design. Participants were randomly assigned to one of two conditions: nature vs. urban, to manipulate their exposure to natural or urban settings. Randomization was implemented by Qualtrics. In the nature condition, participants viewed 14 photographs of nature scenes (e.g., forest, seas, trails), while in the urban condition, participants viewed 14 photographs of urban scenes (e.g., street view, metro, see exemplars in Figure 3). In both conditions, I asked participants to immerse themselves in the scenes when viewing the photographs. Following this manipulation, I assessed their FTP as the

primary response variable and positive and negative affect as the mediator. Finally, participants provided their demographic information, including age, gender, race, and household income.

Figure 3

Sample Photos Used in the Nature (Left) and Urban (Right) Condition



Measures

FTP was measured as in Study 1 ($\alpha = .82$). I measured participants' positive and negative affect with the Positive and Negative Affect Scale (PANAS; Watson et al., 1988). This scale consists of 20 items, 10 for positive affect (i.e., Interested, Excited, Strong, Enthusiastic, Proud, Alert, Inspired, Determined, Attentive, Active, $\alpha = .86$) and 10 for negative affect (i.e., Distressed, Upset, Guilty, Scared, Hostile, Irritable, Ashamed, Nervous, Jittery, Afraid, $\alpha = .87$). Participants indicated the extent to which they feel each feeling after viewing the photographs, using a 5-point scale (1 = *very slightly or not at all*, 5 = *extremely*). Following previous studies, we calculated the overall affect score by substracting the negative affect score from the positive affect score (Koydemir & Schütz, 2012; Liu et al. 2013; Yang et al., 2024).

Results and Discussion

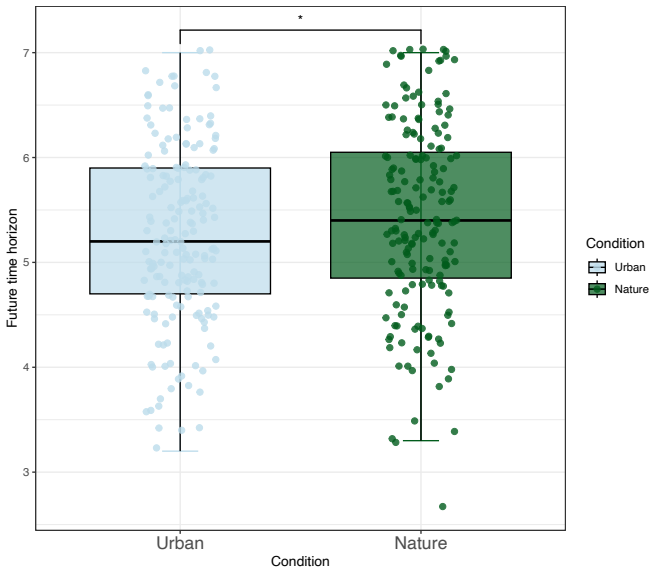
I first tested the group differences in affect and FTP. Participants in the nature condition (M = 1.58, SD = .83) reported significantly more positive (vs. negative) affect than participants

in the urban condition (M = 1.30, SD = .91), t(348) = 2.96, p = .003, d = .32, 95% CI [0.11, 0.53]. Participants in the nature condition (M = 5.43, SD = .90) also reported higher FTP than participants in the urban condition (M = 5.24, SD = .86), t(348) = 1.99, p = .047, d = .21, 95% CI [.00, .42], see Figure 4. The results remain the same after controlling for age, gender, race, and household income, b = .18, p = .056, 95% CI [–.004, .367]. The findings supported the hypothesis that exposure to nature would extend FTP.

I then tested the mediating role of positive (vs. negative) affect. As predicted, its indirect effect was significant, *indirect effect* = .058, SE = .026, p = .026, 95% CI [.015, .115]. Path coefficients are shown in Figure 5. Together, these results supported the proposed effect of nature on FTP, with positive (vs. negative) affect mediating the link.

Figure 4

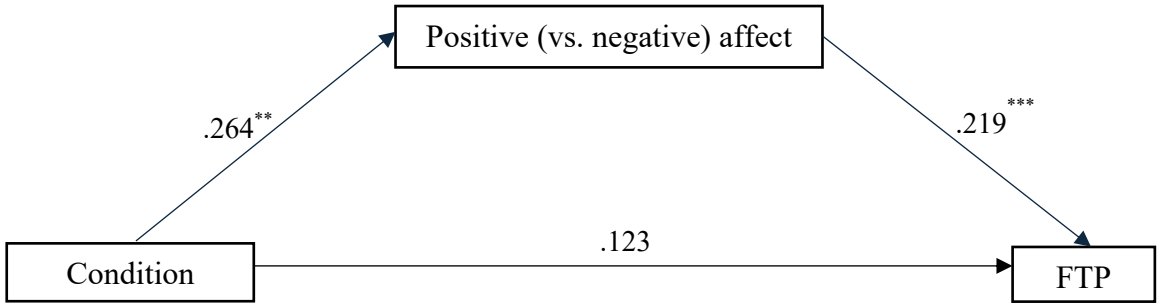
Participants in the Nature Condition Reported Higher FTP than Participants in the Urban Condition



Notes. $^{*}p < .05$. Error bars represent standard error.

Figure 5

The Mediating Effects of Positive Affect (vs. Negative) Affect in the Effect of Exposure to Nature on FTP



Notes. $^{**}p < .01$, $^{***}p < .001$.

Study 3: Nature and FTP: An Experimental Study Testing the Mediating Role of Subjective Vitality

The primary goal of Study 3 was to examine the mediating role of subjective vitality in the effect of nature exposure on FTP.

Method

Participants

In Study 3, I aimed to examine the mediating role of subjective vitality in the causal effect of nature on FTP. I recruited 363 undergraduate students from the University of Oklahoma to the lab and compensated course credits for participation. I excluded 14 participants who failed to pass the attention check (i.e., "*Please select 'Strongly Disagree'* "). Our final sample size reached 349 (70.2% females, M_{age} = 19.11, *SD* = 1.95).

Procedures

I manipulated participants' exposure to nature (vs. urban) as in Study 2. Following this

manipulation, I assessed their FTP as the primary response variable and subjective vitality as the mediator. I also measured their connectedness to nature as a manipulation check. In response to Study 2, I also assessed participants' positive and negative affect. Finally, participants provided their demographic information, including gender, age, race, and household income.

Measures

I measured FTP ($\alpha = .83$) and connectedness to nature ($\alpha = .82$) as did in Study 1. I measured subjective vitality with the 7-item scale Subjective Vitality Scale on a 7-point scale ($\alpha = .89$, 1 = *strongly disagree*, 7 = *strongly agree*; Ryan & Frederick, 1997, see Appendix B). One sample item is "I feel alive and vital". Higher scores indicated higher subjective vitality. I then measured low arousal positive (vs. negative) affect with the 9-item hedonic valence scale on a 7-point scale (1 = *not at all*, 7 = *extremely*; Diener & Emmons, 1984). Positive affect was measured by 4 items (i.e., happy, joyful, pleased, and enjoyment/fun, $\alpha = .88$) and negative affect was measure with 5 items (i.e., depressed/ blue, unhappy, frustrated, angry/hostile, and worried/ anxious; $\alpha = .82$). Again, we calculated an overall affect score by substracting the negative affect score from the positive affect score.

Results

Results are shown in Table 1. Participants in the nature condition reported significantly higher connectedness to nature than participants in the urban condition, suggesting a successful manipulation. Participants in the nature condition also reported higher positive (vs. negative) affect, FTP, subjective vitality than participants in the urban condition. The results remain the same after controlling for age, gender, race, and household income, $b_{positive} = .353$, $SE = .193$, $p = .069$; $b_{future} = .20$, $SE = .093$, $p = .029$; $b_{vitality} = .350$, $SE = .118$, $p = .003$. The findings supported the hypothesis that exposure to nature (vs. urban) would extend FTP.

Table 1

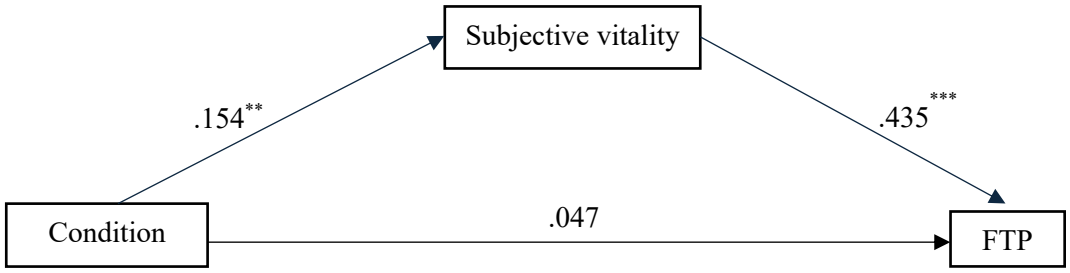
The Effect of Condition (Nature vs. Urban) on Variables in Study 3

Variables	*M* (*SD*)		*t* (347)	*p*	*d,* 95% CI
	Nature: *n* = 173	Urban: *n* =176			
Connectedness to nature	3.40 (.57)	3.15 (.56)	4.16	< .001	.45 [.23, .66]
Positive (vs. negative) affect	4.54 (1.16)	4.28 (1.33)	1.70	.089	.18 [–.03, .39]
FTP	5.25 (.82)	5.04 (.95)	2.18	.030	.23 [.02, .44]
Subjective vitality	4.77 (1.04)	4.43 (1.20)	2.84	.005	.30 [.09, .51]

Then I tested the mediating role of subjective vitality. As expected, subjective vitality significantly mediated the effect of nature on FTP, *indirect effect* = .067, *SE* = .026, *p* = .009, Boot 95% CI [.026, .125] (Figure 6).

Figure 6

Subjective Vitality Mediated the Effect of Exposure to Nature on FTP



Notes. $^{**}p < .01$, $^{***}p < .001$.

Additionally, I replicated the mediating role of positive (vs. negative) affect in the effect of nature on FTP. The indirect effect was not signiticant, *indirect effect* = .039, *SE* = .027, *p* = .151, Boot 95% CI [–.011, .092]. Moreover, I also tested if positive (vs. negative) affect and

subjective vitality mediated the above effect in the serial mediation model. The indirect effect of subjective vitality was significant (Subjective vitality: *indirect effect* = .037, p = .029, Boot 95% CI [.011, .077]; while the indirect of positive (vs. negative) affect was marginally significant: *indirect effect* = .033, p = .092, Boot 95% CI [–.001, .078]).

Discussion

Together, Study 3 replicated the extending effect of exposure to nature (vs. urban) on FTP and revealed the mediating role of subjective vitality in this relationship. Moreover, consistent with Study 2, I found that exposure to nature (vs. urban) increased positive (vs. negative) affect. But the mediating role of positive affect in the effect of nature on FTP was not significant. This may be due to the scale we used which measured low-arousal affect.

So far, our first three studies have provided both correlational and causal evidence for the link between nature and FTP and identified two key mediators: positive (vs. negative) affect, and subjective vitality. All findings, however, are found at the individual level. Next, I examined whether these findings could be generalized to the macro level by examining the relationship between environmental greenspace and residents' FTP at the U.S. County level.

Study 4: Nature and FTP: A Cross-Sectional Study at the County Level

Methods

Data

I aimed to test the relationship between environmental greenspace and people's FTP. For FTP. I used publicly available data from Project Implicit (https://implicit.harvard.edu/), which is an online platform that measures volunteers' implicit attitudes toward several social groups. I obtained dataset of attitudes toward aging people through OSF (https://osf.io/t4bnj). Before data

analysis, I excluded participants who didn't finish the study or were from outside of the U.S. (i.e., including 50 US states and District of Columbia). I also excluded participants younger than 15 years or older than 90 years due to data quality control. Following previous research (e.g., Payne et al., 2019; Tiv & Spence, 2024), I excluded counties with lower then 30 participants to ensure power in multilevel model analysis. After these exclusions, the cleaned data contained a total sample of 772, 956 participants (69.0 % females, M_{age} = 30.12, SD_{age} = 13.87) from 2006-2022, covering 1,686 counties in the U.S. The median sample size per county was 118.

FTP In Project Implicit, participants reported subjective life expectancy, that is the age they hope to live ("To what age do you hope to live"). I thus calculated FTP by subtracting age from the age they hope to live (i.e., perceived years left in their life). I excluded data with negative FTP because it is meaningless under this operationalization.

Greenspace index For greenspace, I used Normalized Difference Vegetation Index (NDVI) as an index of greenness in each county. NDVI quantifies density of green vegetation and is a commonly used indicator of greenspace exposure and nature. I downloaded greenspace data for each US county from 2006-2022 via Google Earth Engine (https://earthengine.google.com/).

Demographics Participants reported the county that they were living, age (or birthyear), gender, education level, race, and political ideology (1 = *strongly conservative*, 7 = *strongly liberal*) in the survey of Project Implicit. Demographic composition of the sample is shown in Appendix C.

Analysis

To examine the relationship between county-level greenspace and individual level FTP, I conducted multilevel regression analysis, with individuals nested in the county. I regressed FTP

on Level-2 county greenness. Previous research suggested some demographic factors that may influence FTP, including age, gender, income, and education (Kooij et al., 2018; Padawer et al., 2007). I then controlled for demographics with age grand-mean centered, race (1 = *White*, 0 = *Non-White*), gender (1 = *Female*, 0 = *Male*) contrast coded, and education level (Roy et al., 2023). Since I have no access to individual income in the dataset, I controlled for per capita personal income by counties as a Level 2 predictor. Data of it was from Bureau of Economic Analysis, U.S. Department of Commerce (https://www.bea.gov/). Specific models including controlled variables are as below:

$$Level\ 1:\ FTP_{ij} = \beta_{0j} + \beta_{1j}Age_{ij} + Gender_{ij} + Edu_{ij} + Race_{ij} + r_{ij}$$

$$Level\ 2:\ \beta_{0j} = \gamma_{00} + \gamma_{01}(NDVI_j) + \gamma_{02}(Per\ capita\ personal\ income) + u_{0j} + v_{0j}$$

$$\beta_{ij} = \gamma_{i0} + u_{ij} + v_{ij}$$

Results and Discussion

I first tested the relationship between greenspace and subjective life expectancy. Results showed that people living in greener county reported longer subjective life expectancy, controlling for age, gender, race, education, and income, $b = .574$, $t = 15.635$, $p < .001$ (see Appendix D). Then I tested the relationship between greenspace and FTP. I first run a null model without any predictors. The ICC revealed that 3.66% of variance was explained by the differences across counties and years. Much more differences were attributed to within county and year. Next, I added the Level 2 NDVI predictor into the null model. It showed that individuals living in greener counties had more expansive FTP, but the relationship was not significant, $b = .125$, $t\ (1995) = 1.557$, $p = .12$, 95% CI [–.032, 0.283]. Then, I controlled

demographic variables[1] and found that NDVI by counties significantly predicted individuals' FTP, $b = .574$, $t\ (1220) = 15.635$, $p < .001$, 95% CI [0.502, 0.646]. Detailed results of MLM are shown in Table 2. Together, these findings supported our hypothesis that nature exposure would be positively associated with FTP.

Table 2

Results from Multilevel Regression Model in Study 4

	Null model	Model 1	Model 2
(Intercept)	60.812 (0.593)***	60.780 (0.595)***	52.727 (1.541)***
Age			–0.974 (0.001)***
Male (Ref=Female)			–0.078 (0.035)*
White (Ref=Non-White)			0.388 (0.039)***
Education			0.102 (0.008)***
Personal income pc (logged)			0.606 (0.144)***
NDVI		0.125 (0.081)	**0.574 (0.037)*****
Marginal R^2	0.000	0.000	0.480
Conditional R^2	0.037	0.037	0.484
AIC	6746474.271	6746477.054	5886602.131
BIC	6746520.503	6746534.844	5886717.106
Num. obs.	772956	772956	727610
Num. groups: GEOID	1686	1686	1648
Num. groups: year	17	17	17
Var: GEOID (Intercept)	7.849	7.818	0.837
Var: year (Intercept)	5.853	5.899	0.411
Var: Residual	360.166	360.167	190.696

[1] In addition to age, gender, race, education level, and county level personal income pc, controlling for political ideology didn't alter our results, $b = .559$, $t = 15.233$, $p < .001$.

General Discussion

Extensive research has documented the psychological benefits of nature on human health, primarily from a present-oriented perspective. However, far less attention has been given to how nature influences individuals' perception of their future, which is essential for life-span development and well-being. The present thesis, for the first time, investigated the impact of nature on individuals' perception of future time left (i.e., FTP) and the underlying mechanisms driving this effect. I postulated that nonthreatening natural environments would extend people's FTP, that is feeling more time available left in their life.

Across four studies, I provided both correlational and causal evidence for the link between nature and FTP. First, I established a culturally invariant correlation between trait-level connectedness to nature and FTP across both American and Chinese participants (Study 1). Then, through experimental manipulations, I demonstrated the causal effect of exposure to nature (vs. urban environments) on FTP (Studies 2 & 3). At the meantime, I identified two key mediators: positive (vs. negative) affect, and subjective vitality (Studies 2 & 3). Specifically, exposure to nature extended FTP via increasing positive (vs. negative) affect and subjective vitality. Finally, I extended our analysis beyond the individual level to a broader ecological context by analyzing how the presence of greenspace in everyday environments was linked to individuals' FTP. Results showed that people living in greener counties exhibited more expansive perception of their future (Study 4). Overall, these studies provided consistent support for the link between nature and FTP across methodological approaches (correlational and causal), cultures (East Asian and Western), and levels of analysis (individual and county) as well as the mechanism underlying it.

Previous research showed that awe induced by magnificent nature can increase sense of time availability (Rudd et al., 2012). The findings extend this research by showing that everyday natural environments, not only awe-inspiring nature, can also expand perceived future time availability. This may be explained by Life History Theory. It posits that all organisms strive to utilize limited resources (e.g., time, matter, energy) to optimize survival and reproduction across the life span (Roff, 2002). In harsh and unpredictable environments, organisms tend to adopt a faster life history strategy, which encompasses early reproduction, rapid juvenile growth, short-term planning, short life expectancy, etc. (Ellis et al., 2009). By contrast, stable and resource-rich environments promote a slower life history strategy, focusing on delayed reproduction, slow juvenile growth, long-term planning, prolonged life expectancy. According to the biophilia hypothesis, humans have an innate affinity for nature, and exposure to beautiful nature usually fosters a sense of peace, spaciousness, and resource abundance. This perceived safety in nature may encourage a slower life history strategy and long-term goal planning, leading individuals to vision further into the future. This indicates an expanded FTP in a natural setting.

In line with previous research (e.g., Bratman, Daily, et al., 2015; McMahan & Estes, 2015; Theodorou et al., 2023), I found the significant effects of nature exposure on positive and negative affect and subjective vitality. The increased positive affect and subjective vitality and decreased negative affect further predicted expanded FTP. These findings confirm the association between affectivity and FTP (Kooji et al., 2018). For the first time, I also revealed that feeling vital was related to longer perception of remaining time left in life. This highlights the role of perceived energy and control in time perception.

Implications

The present study has significant theoretical implications. First, the findings reveal a new effect of nature experience on time perception. While previous research has primarily examined how exposure to nature influenced subjective temporal perception and time perspective (e.g., Berry et al., 2015; Davydenko & Peetz, 2017; Van der Wal et al., 2013), the current research extends a third research line by demonstrating that exposure to nature also lengthens perception of future time availability.

Second, the findings support a novel framework for understanding the factors that shape FTP. Existing research has largely focused on personal factors (e.g., age, health condition, cognition) and situational influences (e.g., major life transitions), which are typically associated with future time constraint (Carstensen & Fredrickson, 1998; Kooij & Van De Vorder, 2011; Lang & Carstensen, 2002; Löckenhoff & Carstensen, 2004). In contrast, this research highlights an environmental factor (i.e., natural environments) as a key influence on FTP. Notably, I provide the first empirical evidence that feeling connected to nature and exposure to nature was linked to, or extend one's FTP, offering new insights into the dynamic relationship between environment and temporal cognition.

Third, I found that positive and negative affect, as well as subjective vitality, mediated the effects of nature on FTP. While the relationship between nature experiences and both affect and subjective vitality is well-established, the findings extend this literature by demonstrating that affect and subjective vitality also serve as key mechanisms influencing FTP. This highlights the crucial role of emotional factors in shaping time perceptions. Moreover, since subjective vitality is closely related to perceived control and autonomy, the findings also suggest the role of these psychological resources in shaping time perceptions.

The current research has practical implications. Since FTP is a malleable cognitive construct that is easily influenced by situations, individuals are easily to feel future time running out, leading to negative physical and mental outcomes. The findings provide a green and sustainable approach to lengthen time perception toward future---building connection to nature. This insight also informs urban planning, emphasizing the importance of integrating green spaces into environments that typically evoke future time constraints, such as nursing homes, hospitals, and recovery centers, and to improve people's sense of time availability for the future.

Limitations and Future Research

I acknowledge that the present work has some limitations. First, in the experimental Studies 3 and 4, I used the same manipulation method of exposing participants to photos of nature or urban scenes. Although this method was widely used in prior research (e.g., Berman et al., 2008; Beute & De Kort, 2014; Jo et al., 2019; Mostajeran et al., 2021; Swami et al., 2018), it was limited in ecological validity due to its reliance on artificial and virtual stimuli. Future research can incorporate more immersive manipulations, such as asking participants to walk in a real or virtual natural environments, and adding natural elements (e.g., green plants) in the room (e.g., Davydenko & Peetz, 2017; Michels et al., 2022; Sudimac et al., 2022; Tanja-Dijkstra et al., 2018).

Second, the present research only examined the effect of mundane, nonthreatening, and pleasant nature on FTP. While pleasant nature is widely studied in related research, increasing evidence has warned of the dark side of nature (Soga & Gaston, 2022), such as natural disasters, poisonous wildlife, pathogens, and allergens. These elements pose serious threats to individuals' physical and mental health (Freedy et al., 1994; Tomalak et al., 2011). Moreover, encounters with wild nature evoked stronger existential concerns about death and freedom than cultivated

nature (Koole & Van den Berg, 2005). Based on Life History Theory, harsh nature signal resource scarcity and survival threats, leading individual to adopt a short-term life strategy. As a result, they are less likely to engage in future-oriented thinking. This suggests that exposure to harsh nature may shorten one's FTP. For example, research found that during COVID-19 pandemic, the increase in regional severity was associated decrease in FTP among young adults (Fynes-Clinton & Addis, 2023). Future research is needed to examine this assumption and provide a broader picture of the effects of nature on FTP.

Conclusion

Humans have the innate ability to envision their future and act accordingly at the present. While some people believe they have a lot of time in the future, some feel future time limited. In this thesis, I found that nature can extend individuals' perception of future time via enhancing positive (vs. negative) affect and subjective vitality. These findings not only extend our understanding about the influences of nature on human psychology, but also have important practical implications for individual well-being and environmental planning.

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Appendix

Appendix A

Connectedness to Nature Scale (Geng et al., 2015; Mayer & Frantz, 2004)

Please answer each of these questions in terms of the way you generally feel. There are no right or wrong answers. Please indicate your level of agreement with each of the following items on a 1 to 5 scale. (1= *Strongly Disagree*, 2 = *Disagree*, 3 = *Neutral*, 4 = *Agree*, 5 = *Strongly Agree*)

1. I often feel a sense of oneness with the natural world around me.
2. I think of the natural world as a community to which I belong.
3. I recognize and appreciate the intelligence of other living organisms.
4. I often feel disconnected from nature. (R)
5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.
6. I often feel a kinship with animals and plants.
7. I feel as though I belong to the Earth as equally as it belongs to me.
8. I have a deep understanding of how my actions affect the natural world.
9. I often feel part of the web of life.
10. I feel that all inhabitants of Earth, human, and nonhuman, share a common 'life force'.
11. Like a tree can be part of a forest, I feel embedded within the broader natural world.
12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature. (R)
13. I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.
14. My personal welfare is independent of the welfare of the natural world. (R)

Future Time Perspective Scale (Carstensen & Lang, 1996)

Read each item and answer the questions: "How true is this of you?" Shade the oval under the appropriate number on the scale, where 1 means the statement is very untrue for you and 7 means that the statement is very true for you.

1. Many opportunities await me in the future.
2. I expect that I will set many new goals in the future.
3. My future is filled with possibilities.
4. Most of my life lies ahead of me.
5. My future seems infinite to me.
6. I could do anything I want in the future.
7. There is plenty of time left in my life to make new plans.
8. I have the sense that time is running out. (R)
9. There are only limited possibilities in my future. (R)
10. As I get older, I begin to experience time as limited. (R)

Appendix B

Subjective Vitality Scale (SVS; Ryan & Frederick, 1997)

Please answer each of these questions in terms of the way you generally feel. There are no right or wrong answers. Please indicate your level of agreement with each of the following items on a 1 to 7 scale. (1= *Strongly Disagree*, 7 = *Strongly Agree*).

1. I feel alive and vital.
2. I have energy and spirit.
3. I don't feel very energetic. (R)
4. I feel alert and awake.
5. I look forward to each new day.
6. I feel energized.
7. I feel so alive I just want to burst.

Appendix C

Table A1

Demographic Compositions and Descriptive Statistics

	N (%)	(NA)	Mean	SD
Age	772956 (100%)		30.12	13.87
Gender	771504 (99.8%)	1452 (0.2%)		
Females	533240 (69.0%)			
Males	238264 (30.8%)			
Race	740755 (95.8%)	32201 (4.2%)		
American Indian/Alaska Native	6078 (0.8%)			
East Asian	22118 (2.9%)			
South Asian	18270 (2.4%)			
Native Hawaiian or other Pacific Islander	5069 (0.7%)			
Black or African American	64618 (8.4%)			
White	546877 (70.8%)			
Other or Unknown	42831 (5.5%)			
Multiracial	34894 (4.5%)			
Education	770365 (99.7%)	2591 (0.3%)	6.11	2.31
Elementary school	374 (0.0%)			
Junior high	6281 (0.8%)			
Some high school	67742 (8.8%)			
High school graduate	83217 (10.8%)			
Some college	241238 (31.2%)			
Associate's degree	73904 (9.6%)			
Bachelor's degree	131758 (17.0%)			
Some graduate school	53497 (6.9%)			
Master's degree	67487 (8.7%)			
J.D.	7365 (1.0%)			
M.D.	5557 (0.7%)			
Ph.D.	14589 (1.7%)			
Other advanced degree	4590 (0.6%)			
M.B.A.	14589 (1.9%)			
Political ideology	759533 (98.3%)	13423 (1.7%)	4.32	1.60
Per capita personal income by county	1686		44276.44	15394.16
NDVI by county	1686		5143.21	1330.00
Age hope to live to	772956 (100%)		89.61	13.88
FTP	772956 (100%)		59.49	19.30

Appendix D

Table A2

Supplemental Results from Multilevel Regression on SLE in Study 1

	Null model	Model 1	Model 2
(Intercept)	89.699 (0.121)***	89.580 (0.128)***	82.255 (1.541)***
Age			0.026 (0.001)***
White (Ref=Non-White)			–0.078 (0.035)*
Personal income pc (logged)			0.388 (0.039)***
Male (Ref=Female)			0.102 (0.008)***
Education			0.606 (0.144)***
NDVI		**0.577 (0.036)*****	**0.574 (0.037)*****
Marginal R^2	0.000	0.002	0.004
Conditional R^2	0.007	0.008	0.010
AIC	6256426.986	6256195.856	5886602.131
BIC	6256473.218	6256253.646	5886717.106
Num. obs.	772956	772956	727610
Num. groups: GEOID	1686	1686	1648
Num. groups: year	17	17	17
Var: GEOID (Intercept)	1.129	0.864	0.837
Var: year (Intercept)	0.221	0.253	0.411
Var: Residual	191.392	191.383	190.696