Moving Bodies, Wandering Minds

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How Movement Enhances Creativity and Language Learning

By

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The skills of action is every bit as important as the skills of knowledge. That this is not recognized in education is a tragedy.
—Edward de Bono (a Maltese physician, psychologist, and author on topics about creative thinking and problem-solving, and well-known for his concept of “lateral thinking”)

I was a fantastic student until 10, and then my mind began to wander.
—Grace Paley (an American author, poet, and teacher)

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PREFACE AND ACKNOWLEDGMENTS

I have always loved to walk. As a child, I walked our dog every night and on the weekends around the park. Then, I started walking longer distances. I began by walking on the Ice Age Trail in the Kettle Moraines of Wisconsin, and then on the Colorado Trail in the Rocky Mountains. My feet took me to many places, like Betws-y-Coed in Wales and the Plaza Zabala in Montevideo. I still walk every day, but I also run now. I do this on roads and trails, at high altitudes, on snow, and anywhere I can find a path. I have joined races and ultramarathons. I am not fast nor am I a competitive runner. Movement is simply a part of my life. It is like the beat of my heart or the rhythm of my lungs inhaling and exhaling. For me, movement is necessary for survival. It's hard to imagine life without movement.

This book was based on a talk I gave at the University of Nagano in 2022 for the Mind, Brain, and Education Special Interest Group (BRAIN SIG), which is part of the Japan Association for Language Teaching (JALT) on mind-wandering. Therefore, I would like to acknowledge JALT's BRAIN SIG, particularly Curtis Kelly (EdD), a former professor at Kansai University and founder of the BRAIN SIG, for his valuable feedback on an earlier version of this manuscript. After that presentation, I became more interested in mind-wandering and how it effects creativity. A moving body and a wandering mind might not seem related to learning, but they both have the potential to enhance creativity. Drawing on research from multiple fields, this book explores how movement and mind-wandering influence creative processes, offering language teachers new pathways to enhance student learning.

I'm also a teacher. For almost 15 years, I've taught English as a foreign language and CLIL (*Content and Language Integrated Learning*) courses at a university in northern Japan. During this time, I've published and done research on creativity, cognitive semantics, embodied learning, and most recently the connection between physical movement and vocabulary learning. As a teacher, I would like to acknowledge the many students who participated in my research and those who took my classes, each cohort inspiring my curiosity and guiding my development as an educator. We have shared a symbiotic relationship, each challenging the other to be more creative and push the boundaries of language education.

In addition, I would also like to thank my former doctorate adviser Dr. Jeannette Littlemore who introduced me to the world of metaphors and creativity and the power they have on our everyday thoughts and language. Although not providing direct guidance on this book, many colleagues and professionals supported me during its research and writing. I would especially like to acknowledge Barry Kavanagh, Brent Kelsen, Wayne Malcolm, Natsuko Tatsuta, Shinichi Sawada, all the Morioka International Athletes (MIA), and to the many others whose conversations and advice enriched this work.

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Finally, I would like to thank my wife and daughter who always provide invaluable diversions and to my parents, who instilled in me curiosity and the resilience to pursue my goals, however difficult.

The content of the book was written entirely by the author. AI tools (including OpenAI ChatGPT-4 and ChatGPT-5 [https://chatgpt.com] and Anthropic Claude 4 [https://claude.ai]) were used during the editing stage to refine grammar and improve readability.

INTRODUCTION

Humans (*hominins*) and chimpanzees (*pan troglodyte*) shared a last common ancestor sometime during the Miocene Epoch, which was about 9.3 to 6.5 million years ago. Chimpanzees are specialized in arboreal movement, meaning they are highly proficient moving among the trees. When on the ground, they are knuckle walkers, moving using their hands and arms. Humans, on the other hand, came down from the trees and evolved to be bipedal and expert movers on two feet. This resulted in a major divergence between the two species. To understand the unique relationship that humans have with movement, consider the following three scenarios:

(1) Since 1980, a race has been held in the small Welsh town of Llanwrtyd Wells every June. The race is 35 kilometers (about 22 miles), which is slightly under a full marathon. It is called the human vs horse marathon. Horses are mammals like humans, but they belong to a different genus (*equus*) and are quadrupeds or animals that adapted for terrestrial locomotion (movement) using four legs similar to dogs, cheetahs, and antelopes. In contrast, humans are primates—mammals with large brains, highly sociable, and primarily adapted for arboreal locomotion such as bonobos, gorillas, and orangutans. In this race, horses usually win, but not by a lot and not every time. In 2004, 2007, and 2022 humans actually won.

(2) In 2022, Dom Whiting, a DJ, cycled through the streets of Dublin playing techno from a turntable mounted to his bicycle. Thousands of strangers joined him biking, roller-skating, or running through the city. They moved through the city streets for over two hours, listening to music. He has done this now in many cities and each one is just as crowded as the last one. People come out and fill the streets, moving to the music.

(3) In Kyoto, monks from the Japanese *Tendai* sect of Buddhism take part in a practice called *Kaihōgyō* (回峰行). This practice is named after the Japanese words for "circling the mountain." During this practice, monks walk and run for a period of seven years. The goal is to reach enlightenment. The monks who choose to follow this practice start by walking or running about 30 kilometers (18.6 miles)

for 100 days in a row. This is done over the first three years. Then, in the fourth and fifth years, the monks do increasingly demanding stages, running 30 km (18.6 miles) for 200 days in a row. In the sixth year, they increase the distance to 60 km (37.2 miles) a day for 100 days. In the final stage, the seventh year, the monks push this distance to 84 km (52 miles) a day for 100 days. Finally, they run 30 km a day for 100 consecutive days.

These three scenarios reveal a number of interesting points about humans. First, humans move more like quadrupeds than our closest ancestors. For example, other primates like chimpanzees and gorillas can move quickly with an initial charge but would never move continuously over an extended distance like a couple kilometers, let alone a marathon distance. They live among the trees, but humans have over time adapted for terrestrial locomotion, using two legs. Long-distance running (e.g., marathons or ultra-marathons) are not fringe sports for elite athletes or those who derive pleasure from pain but are widely done by large numbers of people throughout the world. People often associate marathons with Pheidippides' run from Marathon to Athens (approximately 40 kilometers, 25 miles) during the Battle of Marathon to deliver the victory message. However, Herodotus (1920) told another story of "the herald Philippides, an Athenian and a long-distance runner who made that his calling" (Book 6.105.1) (there are different ways to write his name) and ran from Athens to Sparta (approximately 240 km/150 miles) to ask for help in fighting the invading Persians. Many modern writers have used this latter example to show this ancient endurance feat is not so different from a modern-day ultramarathon (e.g., Hutchinson, 2018; McDougall, 2009). Today, runners are no longer called heralds nor run for communicating military events or strategies but instead run purely for personal challenge and fulfillment. For example, Chicago and New York Marathons attract over 40,000 participants each year and rough estimates suggest that the total number of people who complete a marathon on an annual basis is over 1 million. In addition, ultramarathons have become more popular over the past couple decades, which are races over the standard marathon distance. For example, according to Ultra Running Magazine (n.d.) in North America alone the number of unique runners rose from 8,407 in 2000 to 97,823 in 2024. In short, humans excel at endurance running and this is a unique feature of humans within the primate family.

Second, humans move because they find joy in it. Humans like to move. There is some inherent pleasure to moving whether on our own two feet or by some human invention like a bicycle, a skateboard, or roller-skates. Moving provides us with both entertainment and joy. This form of

movement is like a new form of dance. For example, the DJ built social cohesion among the individuals as they moved through the city streets listening to techno music. Dance has been an essential part of human life for 10,000s of years. It can be found in early human cave paintings. Consider those at Bhimbetka rock shelters in India that date back over 30,000 years. The figures made with fluid movements depict individuals with arms stretched and legs in various positions indicating a sense of rhythmic movement (Mathpal, 1984).

Third, movement for humans has a spiritual side. Meditation is often mistakenly viewed as sitting and being sedentary, but in fact, it often involves movement, usually walking, sometimes running. This is by no means unique to any one religion. To give another example, in Spain, there is a famous pilgrimage called the Camino de Santiago, which includes a network of trails that converge at the tomb of St. James the Apostle (located in Santiago). One route is called the Camino Francés, and this is about 800 kilometers (just under 500 miles) and takes the pilgrims several weeks to complete. Again, movement creates opportunities for discovery—socially, by connecting with others, and mentally, through self-reflection inspired by the simplicity and rhythm of walking along a path. Endurance running as spiritual practice has also been well documented in indigenous people in modern Mexico such as in the Rarámuri (or also referred to as the Tarahumara) who run long distances for both social and spiritual reasons (Lieberman et al., 2020).

However, this book is not about endurance running or doing holy pilgrimages across miles and miles of trails and roads or about techno music and the important role dance plays for humans in the past and now. Instead, I use these examples to illustrate how connected movement is for humans on a wide range of levels. The goal of this book is to extend these ideas and to show the important role movement has for higher order cognitive processes such as language, creativity, and learning. This book encapsulates research done over the past couple decades from varying fields such as cognitive neuroscience, psychology, cognitive linguistics, and educational psychology that highlight how we have to *rethink* the way we *think* about cognition. This includes becoming more aware of the role the body plays in thinking and learning and how essential movement is not only for physical health, but also for emotional and mental well-being. The outline of this book is as follows.

The first two chapters in Part 1 explore the emotional and cognitive benefits of physical movement, ranging from boosting mood to improving memory. Chapter 3 then shifts the focus to the connection between the body and language. For a long time, language was commonly believed to be a

purely cognitive skill, separate from the body and housed within a specialized language module in the brain. However, research in embodied cognition has revealed the deep coupling of the sensorimotor and emotional systems of the body with higher-order linguistic abilities. Finally, Chapter 4 concludes Part 1 by introducing the concept of mind-wandering and the growing body of research on this topic. Movement is fundamental to being human—both in the physical body and in the mind—and these dynamic qualities are crucial for human insight and creativity.

Part 2 begins with Chapter 5, which examines the concept of creativity. Rather than attempting to provide a comprehensive overview of this vast field, the chapter selectively focuses on the cognitive processes underlying creative thought and how researchers measure creativity. Building on this foundation, Chapters 6 and 7 explore recent research on how mind-wandering and physical movement can enhance creativity. Chapter 8 then highlights the importance of cognitive flexibility for creativity. Additionally, it examines the relationship between mind-wandering and mindfulness. To conclude Part 2, Chapter 9 introduces a framework called Mind*flow* Imagination, which describes the optimal conditions for creativity to emerge.

Part 3 connects the ideas from the previous two parts and considers their implications for language education. Chapter 10 examines three deeply ingrained belief structures—or *thinking webs*—in education, arguing that these outdated perspectives need to be revised to foster movement, mind-wandering, and creativity in learning. Chapter 11 presents research demonstrating the important role of the body in learning, including the benefits of gestures and enactment. Chapter 12 then explores the relationship between positive affect and language learning, emphasizing the roles of interest and novelty in the classroom, thereby enhancing learners' positive emotions and engagement. Finally, Chapter 13 considers the impact of generative artificial intelligence (genAI) on creativity and language education. This chapter concludes by proposing an expanded framework for the 4 Cs of education, incorporating 4E Cognition—recognizing that learning is *embodied* (rooted in bodily experiences), *extended* (augmented by genAI and external tools), *enactive* (dependent on action for meaning-making), and *embedded* (situated within specific environments).

PART 1

PHYSICAL MOVEMENT, EMBODIED COGNITION, AND MIND-WANDERING

Being expert walkers, humans migrated to every continent on the planet. This bipedal mode of locomotion shaped our anatomy, physiology, and cognitive abilities, making us long-distance travelers and specialists in endurance movement. Human endurance capabilities may have evolved early through scavenging, which provided humans a diet rich in fats and proteins (Wrangham, 2009). This evolutionary phase required humans to travel long-distances to access meat before others. Some scholars argue that early humans also practiced what is widely known as persistence hunting—a strategy used by early humans who ran, tracked, and walked to drive prey to exhaustion (Liebenberg, 2006). This method also provided important sources of meat and has been suggested to be a key driver of human evolution, influencing the development of our species (Bramble & Lieberman, 2004). While some question the reliability of this hypothesis, recent studies continue to support it, suggesting that persistence hunting was both prevalent and widespread, and that early humans used endurance running to actively hunt animals (Morin & Whinterhalder, 2024). Ultimately, humans evolved to travel long distances either by walking or running, and this daily activity was a major contributing factor in shaping the modern human body (Bramble & Lieberman, 2004).

Movement placed high cognitive demands on these early humans. Wayfinding cognition, for example, enabled them to build rich mental maps of their environment while navigating landscapes. This involved various knowledge structures, including survey knowledge (spatial relationships between places and objects), landmark knowledge (recognition based on appearance), and route knowledge (sequence connections between locations and objects) (Siegel & White, 1975). Additionally, tracking animals required a combination of observational skills, pattern recognition, spatial awareness, and critical thinking. Hunting and movement also depended on social interaction, involving complex group dynamics, effective communication,

and cooperation. Both language and gestures played key roles in this collaboration.

For modern humans, movement is primarily associated with physical health. Regular exercise improves heart health, reduces the risk of diabetes, and lowers the risk of stroke. According to the Centers for Disease Control and Prevention (2023), adults should engage in at least 150 minutes of physical exercise per week based on the current Physical Activity Guidelines for Americans. The World Health Organization (2024) extends this recommendation and advises 150-300 minutes per week. While movement is widely recognized for its physical benefits, cognition has traditionally been viewed as a function of the brain, with the body playing little or no role in higher-order cognitive abilities such as language, thought, and creativity. However, this perspective has been increasingly challenged over the past two decades, as numerous empirical studies have demonstrated the cognitive benefits of exercise.

This first part of the book is divided into four chapters that introduce the key themes. Chapter 1 explores how exercise improves mental health and mood. Chapter 2 examines the connection between movement and cognition, highlighting its potential to enhance memory. Chapter 3 introduces embodied cognition, a field of research that investigates the role of the body in higher-order cognitive processes, particularly language. Finally, Chapter 4 discusses mind-wandering and the growing interest in its cognitive effects over the past two decades.

CHAPTER 1

MIND IN MOTION: HOW MOVEMENT IMPROVES WELL-BEING

Running is my therapy.
—Rob Krar (Ultramarathon runner)

I am extremely happy walking on the downs. … I like to have space to spread my mind out in.
—Virginia Woolf (From her Diaries, 20th century modernist English writer. Note: "downs" here refers to the rolling hills in Southern England)

People move their bodies for all sorts of reasons—to exercise, to work, to escape danger, to dance, to socialize with friends, to find inspiration, to fend off boredom, or to explore new surroundings. Sometimes movement is well-rehearsed and practiced until the body flows without thought, connected to the environment like walking or running along a familiar route or dancing to a favorite song. Other times, it is spontaneous, like a gesture shared when telling an emotional story to a friend. Movement can also be unconscious, such as pacing while waiting for important news or awkwardly shifting weight while standing for a long time in a line at the airport. There is something natural about movement. However, people today are increasingly sedentary—sitting at desks, reclining on sofas, and remaining inactive for much of the day.

Some might argue that we are living in a sedentary age. We wake up and then sit in a car during commute, sit at work or school for 8-10 hours, sit in a car again on the way home, and finally sit in front of our computer or smartphone in the evening. This may sound oversimplistic; however, despite growing awareness and the implementation of physical activity monitoring systems and national strategies worldwide to promote it, physical activity levels have not shown signs of increasing (Sallis et al., 2016).

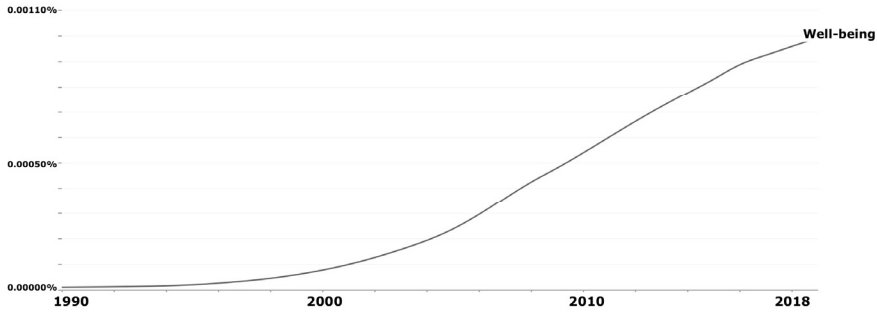
It is also well-documented that a large percent of the human population suffers from many mental disorders. For example, The World Health

Organization (2022) estimates that 1 in every 8 people, or about 970 million people worldwide, are living with a mental disorder such as anxiety or depression. In another study, the Gallup report (2023) asked adults in 142 countries if they had experienced a negative emotion on the day before the survey, the study found that four in 10 adults experienced a lot of worry (41%) or stress (40%). In other words, nobody is immune to mental stress, anxiety, or depression—it is a global epidemic affecting a substantial portion of the global population. Thus, the question is how can movement like running be therapy or lead to positive emotional experiences? How can walking in the rolling hills lead to positive emotions?

As a result of this growing awareness of mental health disorders among the human population, a term called "well-being" began to be widely used and popularized in the media and academia. Using Google Ngram Viewer (n.d.), it is easy to see the sharp rise of its use as a word over a three-decade period (see Figure 1).

Figure 1

Graph of "Well-being" Usage over a Three Decade Period (1990-2020)



The word was rarely used in the 1990s and then in the early 2000s, it saw rapid growth. Analyzing this change, the data shows that there was approximately a 255% increase in usage from 2000 to 2019. This indicates an overall pattern—interest in this term has rapidly increased over the last couple decades. However, defining well-being is likely more difficult, as it means different thing to different people, and like many abstract psychological terms, its definition varies considerably among writers, researchers, and popular media.

Theories of Well-Being: From Hedonia and Eudaimonia to the PERMA Model

One theoretical framework for well-being is to distinguish it into hedonic, subjective well-being (SWB) (Diener, 1984), and eudaimonic, psychological well-being (PWB) (Ryff, 1989; Ryff & Singer, 2008). SWB focuses on life satisfaction and positive emotions while PWB deals with personal growth, purpose, autonomy, and self-actualization. To illustrate these differences, SWB is measured by immediate emotional states and overall life satisfaction (e.g., "I feel happy most days"). In contast, PWB focuses on deeper aspects of well-being beyond momentary happinesss (e.g "I've developed meaningful relationships" or "I have a clear purpose in my work").

Another framework, the PERMA model (Seligman, 2011) is a broad, multidimesnional view of well-being coming from the field of Positive Psychology. This model divides well-being into the following 5 key components: (1) **P**ositive emotions (e.g., contentment and happiness; as opposed to negative emotions such as depression and anxiety), (2) **E**ngagement (e.g., how absorbed one is in an activity; related to Csikszentmihalyi's (1990) *flow theory*), (3) **R**elationships (e.g., feeling connected to others and valued), (4) **M**eaning (e.g., having a purpose in life), and (5) **A**ccomplishment. The question then is, does exercise or physical movement affect these different components of well-being and why?

Positive Emotions (Perma)

The first component is likely most straightforward since exercise is widely accepted as a way of boosting emotional well-being by improving positive emotions and reducing negative emotions like anxiety and depression (e.g., Buecker et al., 2021; Mandolesi et al., 2018; Penedo & Dahn, 2005). Exercise has been shown to be as effective as medication in improving positive emotions and alleviating symptoms of depression—comparable to antidepressants (Kvam et al., 2016) and, in some studies, even more effective than psychotropic treatment (Babyak et al., 2000). In the Babyak and colleagues (2000) study, participants receiving medication and those in the exercise treatment condition all showed signs of reduced depressive symptoms at the end of the 4-month treatment program. However, participants in the exercise group were less likely to relapse after 10 months than those receiving medication. Other studies have corroborated these findings with adolescent participants and those who engaged in physical activities were more resilient to depressive symptoms (McPhie & Rawana,

2015). In contrast, sedentary behavior has the potential to have a negative effect on one's overall well-being by increasing the risk of anxiety (Teychenne et al., 2015) and depression (Teychenne et al., 2010).

The large number of studies that support this viewpoint have prompted The American College of Sports Medicine (n.d.) to recently undertake a global health initiative to promote exercise as a form of medicine. In short, exercise boosts positive emotions, one of the key components of well-being, yet what about some of the other components of well-being?

Engagement (pErma)

Flow states—the psychological experience of being fully immersed and engaged in an activity—are often referred to as an example of "optimal experience" (Csikszentmihalyi, 1990), contributing to positive well-being (Isham et al., 2019) and increased engagement (Sherno et al., 2003). According to Csikszentmihalyi (1990), *flow* is an autotelic experience, meaning, an activity that is pursued and engaged with for its own sake, without external expectations or future benefits. It occurs when there is optimal balance between challenge and skill, where the task's difficulty matches the individual's abilities. In this state, action and awareness merge, allowing for deeper concentration and a sense of control. In the end, the individual loses oneself in the action, experiences a loss of self-consciousness, and become fully absorbed in the activity. Swann and colleagues (2019) explored how exercise can create rewarding experiences by interviewing individuals after physical activity. They found participants experienced *flow* states characterized by enjoyment, reduced perceived effort, and a sense of exploration, novelty, and flexible outcomes. These findings highlight how exercise not only enhances positive emotions but also fosters deeper engagement, creating opportunities for learning and creative insight.

In regard to physical exercise and engagement in an academic setting, aerobic exercise interventions can effectively be used to enhance student engagement in learning. For example, research shows that even low amounts of physical activity or participation in sports increased the likelihood of flourishing and academic engagement for adolescents with obesity (McCoy & Rupp, 2021). Additionally, aerobic exercise positively impacts middle school students' overall academic engagement and enhances academic buoyancy (Ren et al., 2025). Academic buoyancy refers to the student's ability to deal with the routine everyday struggles of learning—overcome academic setbacks and challenges, and pressures students face on a daily basis (e.g., poor test scores, difficult assignments,

etc.) (Martin & Marsh, 2008). Having good academic buoyancy provides students the ability to bounce back from everyday setbacks and sustain engagement.

In sum, physical activity promotes states of *flow* and engagement with the activity, and this includes in sports and academic environments. There is also the potential that physical activity can enhance students' academic buoyancy, thus preparing them for greater future challenges.

Relationships (peRma)

Physical activity creates a platform for relationships to be built and flourish. Even in individual sports like running, this is frequently done through social engagement with others and through these shared experiences, deeper connections are formed, and meaningful relationships develop. These relationships can occur both in person and online through apps that track physical activities like Strava, which has recorded over 100 million active users to its platform (Strava, 2023). Another popular concept in the running community is *Parkrun* (n.d.), a weekly, community-based, free 5 km or 2 km run that is highly accessible to runners of all levels, taking place in hundreds of locations across 22 countries. Parkrun fosters a sense of community and connection, contributing to improved personal well-being among the participants (Grunseit et al., 2018).

Additionally, research shows that participating in physical activities like a sport promotes several benefits for social health such as stronger social connections, trust, and cooperation (Linver et al., 2009) and a sense of community and belonging (Eime et al., 2013). These studies demonstrate how movement can improve social well-being and relationships between people, the third component of PERMA.

A Sense of Purpose/Meaning (perMa)

The fourth component of well-being, having a sense of purpose, is often defined as "a central, self-organizing life aim that organizes and stimulates goals, manages behaviors, and provides a sense of meaning" (McKnight & Kashdan, 2009, p. 242). It has been metaphorically described as a "compass" (McKnight & Kashdan, 2009) or a "lighthouse" (Hill et al., 2013), as it provides direction and guidance in life. Being guided by a strong sense of purpose is associated with optimal health and well-being. In other words, without purpose it is easy to get lost in darkness and fog, living aimlessly without any direction or goals. A sense of purpose has been consistently linked to physical activity (Hill et al., 2019; Hooker & Masters,

2016) and individuals with higher sense of purpose are less likely to adopt a sedentary lifestyle (Kim et al., 2020). This effect between physical exercise and a sense of purpose is bidirectional, which means that people who have a greater sense of purpose are likely to exercise more and at the same time, physical exercise can enhance a sense of purpose in life (Yemiscigil & Vlaev, 2021).

Zhao and Yin (2014) found a similar positive relationship between a sense of purpose and exercise among college students in China. In Japan, there is a term called *ikigai* (生き甲斐), that is a strong indicator of well-being, loosely translated into English as a reason for being or sense that life is worth living (Lomas, 2016). Researchers using rural dwelling Japanese participants, who were over 40 years old, found that physical activity was associated with *ikigai* (Kabasawa et al., 2021). Interestingly they measured physical activity using farm work (spring—autumn months) and snow shoveling (winter months). These studies highlight the deep relationship between a sense of purpose and physical activity across cultures, age groups, and different measurement methods for physical activity.

Accomplishment (permA)

The fifth and final component of well-being in the PERMA model is accomplishment. Physical activity is often linked to a sense of accomplishment, as it involves progress, improvement, and overcoming limitations. This fosters a feeling of achievement and enhances one's sense of competence, whether in running, dancing, shoveling, or simply walking. Using physical activity as an intervention within a school setting has shown to increase self-concept and self-worth in children and adolescents (Liu et al., 2015). In one study, the authors explored how various contextual factors—such as location, type of activity, social interactions, and timing—affect individuals' perceived mood and wellbeing after exercise (White et al., 2023). Using an open-ended questionnaire for data collection, followed by thematic analysis, they found physical activity provided opportunities for self-improvement and emotional well-being. This sense of accomplishment led to various positive emotions, including "euphoric mood, pride, happiness, calmness, and confidence, as well as a sense of feeling able to take on anything" (White et al., 2023, p. 3). Different types of physical activities fostered a sense of accomplishment in distinct ways. In sports, it came through the learning process while in exercise-based contexts, it arose from improving one's skill set. In resistance training, immediate numerical feedback—such as lifting heavier weights or increasing repetitions—led to a sense of accomplishment. Some participants felt proud of the effort they

put into the activity, while others derived a sense of accomplishment from their persistence in maintaining the activity over time (White et al., 2023).

In summary, based on Seligman's (2011) 5 key components of well-being, exercise has the potential to enhance each component and thus improve the overall well-being of the individual. The why question is less understood. Why does physical activity improve mental well-being?

Physical Exercise and Well-being Connection

Why would an activity that is physically demanding and stressful on the body enhance well-being, from fostering positive emotional states to providing the individual a sense of purpose in life? While there may be no definitive answer, several plausible and interconnected frameworks offer valuable insight into this complex question. These include the therapeutic effects of nature exposure, neurobiological mechanisms like endorphins and endocannabinoids, physiological factors such as thermogenesis and neurotransmitter activity, anti-inflammatory responses, and psychological benefits including mastery and self-efficacy. The following sub-sections briefly explore each of these perspectives, demonstrating how they contribute to the well-being benefits of physical activity.

The Power of Nature

Philosophers and poets have talked about the power of nature on the mind and body for countless centuries. "Lose yourself in nature and find peace," a quote often attributed to Emerson suggests how nature can reduce anxiety and stress and help one to discover inner tranquility. The ancient Greek physician, Hippocrates also suggested, "nature is the best physician," which likely can be interpreted as meaning fresh air and being outdoors play a significant role in maintaining health or recovering from an illness. Modern healthcare providers are also re-realizing this benefit and prescribing "nature pills" to motivate patients to enjoy a nature break as part of the healing process (Wessel, 2017).

Physical activity is often done in nature—running or walking in the park, hiking in the mountains, bicycling, or surfing—therefore it is easy to consider how the mental benefits of exercise might arise from being outdoors. There is substantial research showing that being outdoors, breathing the fresh air, being exposed to green spaces, and forest bathing (i.e., *shinrinyoku*, 森林浴) improve mood and health (McMahan & Estes, 2015). Physiologically, being in nature lowers cortisol, the stress hormone, and as a result fosters a sense of relaxation. Additionally, spending time in

a forest strengthens the immune system and promotes overall health, which positively impacts well-being. For example, trees release essential oils containing phytoncides, which, along with reduced stress hormone levels, may enhance the production of natural killer (NK) cells. These cells play a crucial role in boosting immune function and overall health (Li, 2010). However, a lot of exercise is also done indoors—in gyms, swimming pools, dance studios, classrooms, so the positive emotional boost of being in nature only provides a partial explanation.

Runner's High: The Endorphin Hypothesis & Endocannabinoids

Despite the physical demands of running, many runners describe a blissful post-run state of well-being. They describe how the movement felt effortless, time and place faded, as they entered a *flow* state widely known as "runner's high." Clinically, this experience includes anxiolysis (reduced anxiety), analgesia (reduced pain), sedation (a sense of calm) and euphoria (intense joy) (Fuss et al., 2015). For decades, scientists have sought to understand the biological mechanisms behind this euphoric state. The most well-known explanation, often referred to as the "endorphin hypothesis" (Moore, 1982; Thorén et al., 1990), suggests that this phenomenon is linked to the increased secretion of β-endorphins during exercise.

Over the years, researchers have raised questions about the endorphin hypothesis, noting that the link between exercise and endorphins remains ambiguous and that endorphins are too large to cross through the blood-brain barrier (Dietrich & McDaniel, 2004). While endorphins may help reduce muscle pain during exercise, they are unlikely to be the primary cause of "runner's high" (Dietrich et al., 2004; Fuss et al., 2015; Matei et al., 2023; Siebers et al., 2021).

Recently, researchers have focused on endocannabinoids as a more plausible explanation, as they are associated with enhanced well-being, reduced anxiety, and pain relief during endurance exercise (Dietrich & McDaniel, 2004; Heijnen et al., 2016; Siebers et al., 2021). The term endocannabinoid comes from the Greek-derived prefix "endo," meaning within or inside and "cannabis," as these compounds interact with the same receptors as tetrahydrocannabinol (THC), the psychoactive component of cannabis. There is a growing consensus that physical exercise interacts with the endocannabinoid system, which plays a significant role in cognitive function, emotional regulation, memory, and syntactic plasticity (Matei et al., 2023). Resulting in the following conclusion, physical exercise "is considered a valuable non-pharmacological therapy that is an immediately available and cost-effective method with many health benefits, one of them

being the activation of endogenous cannabinoids to reduce stress and anxiety and improve wellness" (Matei et al., 2023 p. 17).

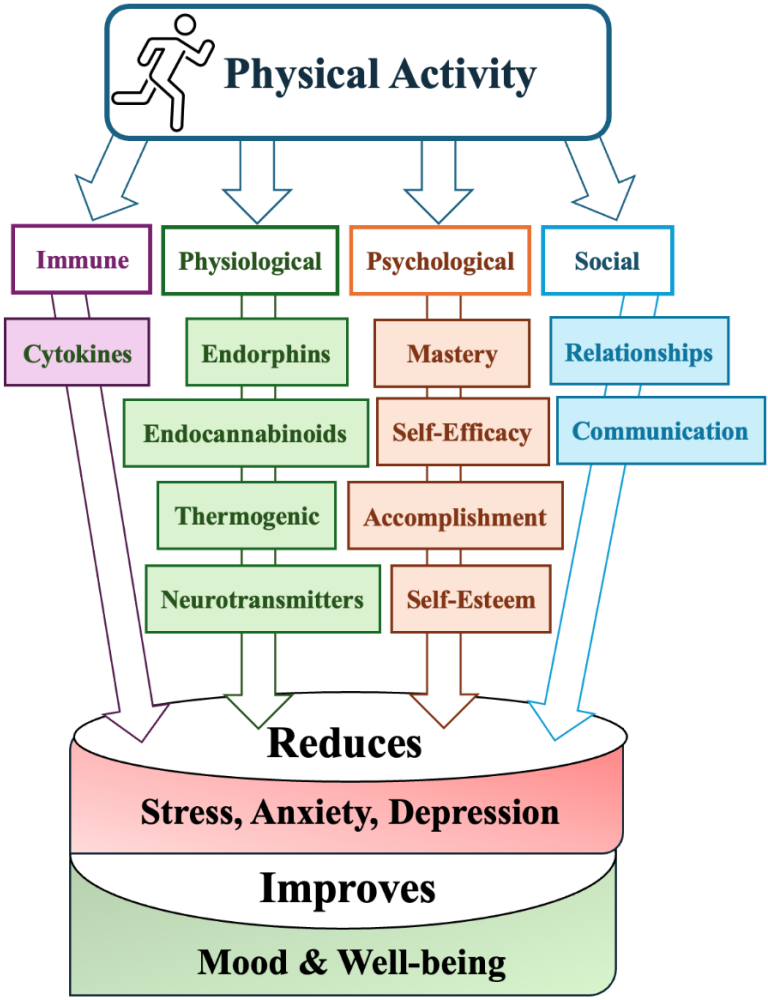
However, this state of a "runner's high" or reaching this euphoric state of *flow* and bliss usually only occurs during moderate to high intensity runs, so again this does not explain why a slow-paced walk improves well-being. Additionally, exercise does need not be aerobic to be associated with mood enhancement, as yoga has consistently been shown to benefit mood (Berger & Owen, 1992), so there must be other explanatory perspectives for the connection between physical activity and well-being.

Other Pathways Physical Activity Promotes Well-being: Physiological

There are several other complex ways that exercise promotes well-being. Using a figure helps visualize these multiple interconnected dimensions, each contributing to health and improved quality of life (see Figure 2). Physiological factors like endorphins and endocannabinoids have previously been discussed. Two other physiological factors that could reduce stress, anxiety, and depression in the individual from engaging in physical exercise are the thermogenic hypothesis (Koltyn, 1997) and neurotransmitters.

Exercising increases body temperature and this homeostatic change is similar to anxiety-induced physiological changes. Why would this be good? One reason is that repeated physical activities may facilitate tolerance to stress and anxiety (Lim et al., 2008). A second reason, as exercise elevates body temperature, the brain senses this increase, and a muscular relaxation response is triggered. The brain then interprets this sensation as relaxation, reducing anxiety (Petruzzello, 2012). This ability to lower anxiety levels is often referred to as anxiolytic effect and other thermogenic activities like taking a sauna similarly effects the body by promoting relaxation and lowering stress. Furthermore, the rise of core body temperature and exercise training has been shown to upregulate the expression of heat shock proteins (HSPs). HSPs protect and repair cells under stress and act as molecular chaperones, i.e., proteins that maintain cellular health and function. These chaperones protect against various pathological conditions, including diabetes (Lappalainen et al., 2010) and insulin resistance (Archer et al., 2018) and may reduce inflammation and neurodegeneration (Beretta & Shala, 2022), thus support mental well-being and mental resilience.

Figure 2
Complex Pathways How Exercise Improves Well-being (adapted and modified from Mikkelsen et al., 2017)



Neurotransmitters are chemical messengers that transmit signals between nerve cells (neurons) in the brain and throughout the nervous system. They regulate physiological processes such as mood, emotions, motor action, and cognitive function (see Snyder & Ferris, 2000 for a review). Exercise can alter the release and uptake of neurotransmitters. For example, endorphins are neurotransmitters that are like natural painkillers, boost mood, and have some effect in producing the "runner's high." Besides endorphins, exercise also increases the release of serotonin and dopamine. These are small-molecule transmitters and have a quick effect on nearby cells.

Serotonin is commonly referred to as the "feel good" neurotransmitter, and increased levels are associated with enhanced mood during physical activity. It also plays a key role in movement, appetite, and the sleep-wake cycle. For decades, low levels of serotonin—often described as a "chemical imbalance"—have been widely believed, both in academia and in the public sphere, to be a cause of depression. However, a large systematic review published in 2023 found no convincing evidence to the support the serotonin hypothesis (i.e., that serotonin imbalance is the biochemical basis for depression) (Moncrieff et al., 2023). This finding has led to considerable amount of debate and criticism, highlighting the evolving nature of research in this area and the fact that evidence remains far from conclusive.

Dopamine is also produced during physical activity and plays a key role in motivation and the brain's reward system. Increased dopamine activity in the ventral striatum enhances reward processing, making activities feel more pleasurable and encouraging future engagement in physical exercise (Bothe, 2013). The dopamine system creates a reward loop—a positively reinforcing environment that motivates individuals to seek natural rewards by repeating certain behaviors. In this process, dopamine regulates the "wanting" or drive to do something, like exercising, and functions independently from systems responsible for "liking" or pleasure (Knab & Lightfoot, 2010). Research supports the potential of aerobic exercise to influence reward-based processing, and studies have found reciprocal effects between physical activity and dopamine-related brain activity (Gorrell et al., 2022).

In summary, exercise triggers the release of several neurotransmitters, which play key roles in mood regulation, motivation, and well-being. Yet, questions remain about the mechanisms underlying these changes, individual differences, and the effect of different types of physical activities (i.e., aerobic, strength training, yoga), and the optimal length of time required to do the activity.

Besides physiological factors, another possible pathway where exercise positively effects mental health is how it reduces inflammation. Inflammation is normal and necessary response for immune function. However, chronic inflammation can damage tissues and contribute to diseases such as Alzheimer's, atherosclerosis, and diabetes (Akiyama et al., 2000; Lontchi-Yimagou et al., 2013). It has recently come to light that the immune system plays an important role in the development of several mental disorders including anxiety and depression (Dantzer et al., 2008; Mikkelsen et al., 2017). Chronic inflammation occurs when pro-inflammatory molecules enter the brain and activate brain immune cells (microglia), leading to neuroinflammation and amyloid build-up, which has been linked to Alzheimer's disease. On the other hand, regular physical exercise promotes the production of IL-6, a cytokine that has anti-inflammatory effects (Chen & Nakagawa, 2023). In short, "the positive effects of exercise on mental health may well be due to the ability of exercise to reduce inflammation" (Mikkelsen et al., 2017, p. 53).

Other Pathways Physical Activity Promotes Well-being: Psychological

There are also psychological pathways between physical exercise and well-being. Exercises from dance to running to bowling all involve a sense of mastery. When one is able to do a twirl, run a 10 km race, or hit a strike, these experiences elevate mood. As a result, an increased sense of mastery is associated with positive psychological states while a low sense of mastery is connected to psychological distress (Dalgard et al., 2007). This creates a spiral effect: as people gain a greater sense of mastery, they are more likely to engage in physical activity in the future, which helps them develop new skills, experience more positive states, and enhance their well-being.

Self-efficacy, based on the work of Bandura (1977), refers to the individual's belief system to perform a specific task or action. For example, someone with high self-efficacy might be confident enough to dance or run, while someone with low self-efficacy might avoid these activities. This avoidance behavior, particularly in regard to exercise-related activities, may prevent the individual from reaping the mental health benefits associated with physical exercise.

Another psychological construct is physical self-esteem, which refers to how individuals feel about their body, fitness level, and physical abilities. A study with university students found that physical self-esteem acted as a mediator between physical activity and quality of life (QOL) (Joseph et al., 2014). QOL was measured by a Likert-type response to the 5-item