UNIVERSITÉ DU LUXEMBOURG

PhD-FHSE-2025-007

The Faculty of Humanities, Education and Social Sciences

DISSERTATION

Defence held on 28/03/2025 in Esch-sur-Alzette

to obtain the degree of

DOCTEUR DE L'UNIVERSITÉ DU LUXEMBOURG

EN *PSYCHOLOGIE*

by

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MONTHS TO MINUTES – VIEWS OF AGING DYNAMICS ACROSS SHORTER TIMELINES

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Keywords: short-term variations, views of aging, predictors of subjective age, within- and between-person fluctuations, AARC, subjective accelerated aging.

"The great thing about getting older is that you don't lose all the other ages you've been."

Madeleine L'Engle, *The New York Times (April 25, 1985)*

Dedication

To my beloved children, Jakob and Oscar. Your love and fun have provided opportunities to relax and recharge. I wish for you nothing less than to grow old and happy.

To my dear partner, Gil, growing old with you can only be a success. Thank you for standing by me through this journey. Your love, patience, and support have been invaluable in making this possible.

To my parents, thank you for your unwavering love and support. Your home is a lighthouse in my journey through life, a steady light that guides me both outward and back home.

Acknowledgements

Research is not performed in solitude, and several people have contributed to my work throughout the PhD journey. During this journey, I have met many clever people who have offered support and their expertise, all of which have contributed to this final work.

Above all, I am immensely grateful to my supervisor, Anna E. Kornadt. Your unwavering support has been a core part of my drive to complete this mission. Your vast knowledge and work capacities have made you my biggest role model throughout this journey. Thank you for all your guidance, support, and belief in me. This has involved not only professional mentorship and connecting me with international collaborators but has also entailed more personal support when life has taken its turns.

I also want to thank my supervisory committee, Isabelle Albert and Claus Vögele. Your expertise and guidance contributed in shaping both my work and my journey toward becoming a researcher.

I would also like to extend my gratitude to my defense jury: Susanne Wurm, Yannick Stephan, as well as Philip Santangelo, who serves as the jury president. I appreciate your interest in my research topic, the time you have dedicated to evaluating my work, and attending my defense.

I am grateful to everyone who played a role in the studies included in this work. I want to express sincere gratitude to all participants who have contributed to the data. Each one of you has provided important feedback on your views of aging and related topics. I want to direct a special thank you to the Hausemer family for actively engaging in the recruitment process of one of the studies. Thank you to all the student assistants with whom I worked closely in order to run my study. Your commitment and discussions have been truly valuable in shaping my work. I also want to thank all collaborators on each of my manuscripts for your support and contributions. I find that your comments have not only improved the manuscripts but also helped me reflect and learn as a researcher.

A big thank you to the Institute of Lifespan and Family Development. I am grateful for all of you contributing to a warm and welcoming atmosphere across age, culture, and experience. Our professional and private exchanges have helped me evolve throughout this process and have made my time at the institute unforgettable. Thank you to Dalia Dirmaite, your knowledge and support have been invaluable, you always have an ear to lend and solutions to give. Last but not least, thank you to everyone I have shared office with during the years, especially to Hannah, Elham, and Gabriella, who have provided support and laughter.

Authors' Contributions

In this thesis, I will present the results and implications of three individual studies, using the pronouns I/my and we/our interchangeably, as they all involved collaborative efforts. With this section, I want to describe the role of me and coauthors in relation to each of the three manuscript chapters. For the published study, this information is copied from the final printed version.

Chapter 2: Data was received from the CRISIS study, conducted at the University of Luxembourg under Principal Investigator Isabelle Albert. Formal analysis: Maiken Tingvold, Anna E. Kornadt. Funding acquisition: Isabelle Albert. Methodology: Maiken Tingvold, Anna E. Kornadt. Project administration: Isabelle Albert. Supervision: Anna E. Kornadt. Visualization: Maiken Tingvold. Writing – original draft: Maiken Tingvold. Writing – review & editing: Isabelle Albert, Martine Hoffmann, Elke Murdock, Josepha Nell, Anna E. Kornadt.

Chapter 3: I used data from the project 'Subjective AGES': Subjective Aging within Global Everyday Ecological Studies, which is part of an international research consortium. PI for the German data collection used in my paper is Anna Kornadt, I was responsible for the conceptualization and statistical analysis, supervised by Anna Kornadt. I drafted the original version of the manuscript, which was revised by all coauthors, after which I organized feedback iterations

Chapter 4: Maiken Tingvold and Anna Kornadt contributed to conceptualization; Maiken Tingvold, Anna Kornadt, and Nanna Notthoff were involved in methodology; Maiken Tingvold and Lisa Borgmann contributed to investigation and data curation; Maiken Tingvold was involved in formal analysis and writing—original draft preparation; Maiken Tingvold, Anna Kornadt, Nanna Notthoff, and Lisa Borgmann contributed to writing—review and editing; and Anna Kornadt was involved in resources and supervision.

Abstract

Aging is an ongoing journey from birth to death. Throughout life, we encounter aging in ourselves and others. As people become older, the relevance of aging becomes more pronounced. While aging can be viewed negatively, suggesting declines in health, social standing, or social networks, it can also be perceived positively as a sign of growth and achievement. Aging and how we view the aging process must be understood from a developmental lifespan perspective to fully capture its lifelong process.

Views of aging, which capture how we view the aging process, are potent factors in more successful aging as they predict a broad range of developmental outcomes (Westerhof et al., 2023). Given the strong connection between views of aging and developmental outcomes in later life, it is essential to gain a better understanding of the underlying drivers that cause people to, for example, feel younger or older. Additionally, we should explore the mechanisms of such factors that influence perceptions of aging beyond long-term timelines. Understanding what drives fluctuations in views of aging can increase our understanding of how people construe their views of aging and how this relates to different developmental outcomes, as well as inform future efforts to improve aging. To do this, we must examine short-term fluctuations of views of aging over more detailed timescales, such as across months, across days, and from moment to moment. As a result, a new stream of research has emerged based on the idea that aging and the formation of age identity occur within the context of everyday life.

Although short-term fluctuations in subjective age have been documented, we know far less about what conditions and contextual factors may impact these fluctuations compared to long-term fluctuations. By focusing on short-term fluctuations in views of aging, we can enhance our understanding of both within-person and between-person variations. Additionally, there is limited knowledge regarding the drivers of these short-term

fluctuations. The current thesis aims to deepen our understanding of how views of aging change over shorter time periods and to examine the various contexts that are linked to these fluctuations.

I will begin this thesis by presenting views of aging and providing an overview of their conceptualizations and operationalizations. I will further explore theoretical frameworks and empirical research that illuminate how perceptions of aging can be understood from various temporal perspectives and current empirical findings. My motivation has been to explore whether we observe significant fluctuations in views of aging using various timescales. I also seek to comprehend the contexts and factors that may lead to these fluctuations. The second part of the thesis presents the empirical papers in which I aim to answer the questions I raised in the introduction.

The first manuscript will investigate views of aging across months in the context of a historical and societal event: the COVID-19 pandemic. This chapter provides insight into how major, socially shared life events can influence how people age. More specifically, we examine how older people's perceived risks of contracting COVID-19, as well as the potential for serious illness from a COVID-19 infection, and their worries about this situation affect their views of aging. This is further seen in the context of how one experiences one's health at a given time, and we explore how additional conditions, such as perceived health status, impact this association.

The second manuscript demonstrates how daily variations in subjective aging are influenced by the perception of health problems. People's positive and negative perceptions of aging provide an internal context moderating this association. This study includes several measures of subjective aging to account for the multidimensional nature of subjective age.

The third manuscript examines fluctuations in views of aging within a very brief timeframe, that is, within a given day. We explore how momentary physical activity, assessed by objective sensor measurement, may lead to differences in subjective age among

individuals and how particular physical conditions create an internal context that can affect this association.

In summary, this thesis provides new insights into how subjective age fluctuates over shorter timeframes, such as months, days, and moments. Additionally, it offers insights into the factors, such as health and pain, that drive these fluctuations and how these forces may be interconnected. The results are discussed in the context of existing theoretical propositions and relevant literature.

Please note that Chapters 2 to 4 come from printed and submitted editions. Minor modifications have been made to maintain consistency in formatting and terminology. Correspondence should be directed to Maiken Tingvold at maiken.tingvold@uni.lu

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Preamble

Chapter 1 - General Introduction

1.1 The Importance of Studying Views of Aging

A Growing Need for Knowledge About Aging

The relevance of aging and older people in society is increasing. In 2019, there were 1 billion people aged 60 and older worldwide, which is expected to reach 2.1 billion by 2050 (World Health Organization, 2024). This increase in the number of older people demands societal adjustments across sectors, especially in health care, social services, and political decision-making institutions. To be effective and accepted, these adjustments must be based on empirical research providing knowledge on today's older adults. Thus, we must better understand the impact of a changing older population on the aging processes.

Today, older people are not only living longer but also healthier and enjoying longer periods of independent living than previous generations did in their later lives (Cohn-Schwartz & Gerstorf, 2022; Hülür et al., 2016). As the aging population grows and their conditions change, research on how people age, their perceptions of their aging, their well-being throughout the second half of life, and how to promote better aging should be a high priority. Failing to do so may be costly on both societal and individual levels. Furthermore, promoting age-friendly institutions has the potential to not only reduce the load on the welfare system but also increase its capacity. If we do not prioritize research on older people, support and intervention programs aimed at helping them may be ineffective and, in the worst case, harmful. For example, younger-old adults may stay part of the active workforce longer, and interventions/practices toward older people in the workplace are associated with changes in their performances (Weiss & Weiss, 2019). At the individual level, research can inform us how to better promote healthy aging and well-being as people age.

More specifically, we need to understand how age identities develop and change, as people will expect to live longer as "old" compared to previous cohorts. How do adults perceive their own aging, and how are these perceptions changing? For example, adults across the globe have been shown to feel younger than their chronological age, but adults today (in northern America) feel younger than adults a decade ago (Gerstorf et al., 2020). This has been argued to be caused by, for example, improvements in health, demonstrating that people's internal and external factors influence their aging development and identity. This example also underlines that with new cohorts and concurrent historical changes, we will likely see changes in how people view and experience their age and aging processes. Further empirical work is therefore needed on what allows people to age well, especially in terms of their age identity formation, its relation to the situational contexts, and interaction with aging-relevant factors such as health.

Subjective Aging – A Link Between Psychological, Social, and Biological Aging

In many fields, chronological age is the main reference point for human development. However, this measure has proven to be ineffective in the context of aging, as many late-life milestones do not follow it (Gerstorf & Ram, 2013). For example, comparing people in their late sixties may demonstrate very different functioning: whereas one person may still be in active work, another may have been forced into early retirement after reduced cognitive functioning. Aging is also a psychological, societal, and cultural process. How individuals experience age and aging, as well as their own development, is often more informative of how people age than merely considering biological and chronological factors (Diehl et al., 2014).

Personalized views of aging (hereby referred to as views of aging) refer to how people perceive their own aging process and age-related stereotypes. Views of aging have typically been measured by asking people either how old they feel in comparison to their chronological age (subjective age) or to report their awareness of having experienced age-related gains and

losses. Views of aging, especially subjective age, have proven to be potent constructs when we want to understand what makes people age well, as research shows that the impact of subjective views of aging on predicting health outcomes (Westerhof et al., 2023), cognitive decline, hospitalization risk (Stephan et al., 2016), proximity to death, and mortality (Kotter-Grühn et al., 2009; Stephan, Sutin, & Terracciano, 2018) surpasses that of chronological age.

Views of aging are associated with psychological, social, and biological factors across different domains. It is related to biological aging in terms of its associations with biomarkers (Kornadt et al., 2022; Stephan et al., 2015b), social aspects in terms of relationships and loneliness (Spitzer et al., 2022), and psychological aging in terms of its associations with depression (Rippon & Steptoe, 2018) and anxiety (Avidor et al., 2021) (the most common psychological troubles of older adults), as well as cognition (Qiao et al., 2021). In addition, Views of aging are associated with a ray of developmental outcomes such as well-being (Debreczeni & Bailey, 2020), health, and longevity (Westerhof et al., 2023). Views of aging, therefore, offer a potential key to understanding the aging process of older people across domains of aging, its different mechanisms, and how it leads to a spectrum of developmental outcomes. This knowledge can further inform the creation of interventions, including psychoeducation of older individuals targeting age stereotypes/misconceptions, and political policymaking and information campaigns.

1.2 Views of Aging – The Experience of Growing Older

Views of aging is a broad term that encompasses both societal and personal perceptions, attitudes, and expectations toward the aging process, old age, and older people. It has been conceptualized as an umbrella term that subsumes related subjective aging constructs. A conceptual hierarchy has been proposed (Shrira et al., 2022) that splits views of

aging constructs into two categories: generalized views of aging and personal views of aging (Figure 1).

Generalized views of aging include commonly held beliefs about aging and older people as a social group. For example, the belief that older adults are frail or unable to learn. Other generalized views can be age stereotypes or essentialist beliefs about aging, which refer to whether one sees aging as a deterministic or malleable process. Essentialist beliefs about aging have been linked to worse physical health and increased aging anxiety (Weiss & Diehl, 2020; Weiss et al., 2016). These societal views predominantly operate outside of the individual's awareness (Shrira et al., 2022).

Personal views of aging refer to individual representations of growing older and being old, such as how old one feels, or at what rate one experiences to be aging. At this level, views of aging are considered to operate mainly on a conscious level, as people are mostly aware of and reflect on their own aging process. Personal views of aging are shaped by a person's life experiences, personality traits, and psychological processes (Diehl et al., 2014). Generalized- and personal views of aging are not independent. For example, stereotype embodiment theory (SET) (Levy, 2009) states that age stereotypes are integrated into a person's views of aging early in life but stay latent, subconsciously, until the person reaches an age at which these beliefs apply. Then, the stereotypes become self-relevant and likely influence one's personal views of aging.

This thesis focuses on personal views of aging through its subconstructs: subjective age (how old one feels), awareness of age-related changes (recognizing personal gains and losses due to growing older), and accelerated aging (the perceived speed of one's aging). These operationalizations are marked in blue in the following Figure 1.1. To ensure clarity, I will refer to "views of aging" and "subjective aging" interchangeably throughout this thesis when discussing personal views of aging measures. It is also worth noting that most research has been conducted on subjective age, while other subjective aging constructs are

comparatively underrepresented in the literature. Consequently, most statements about views of aging will be based on research on subjective age.

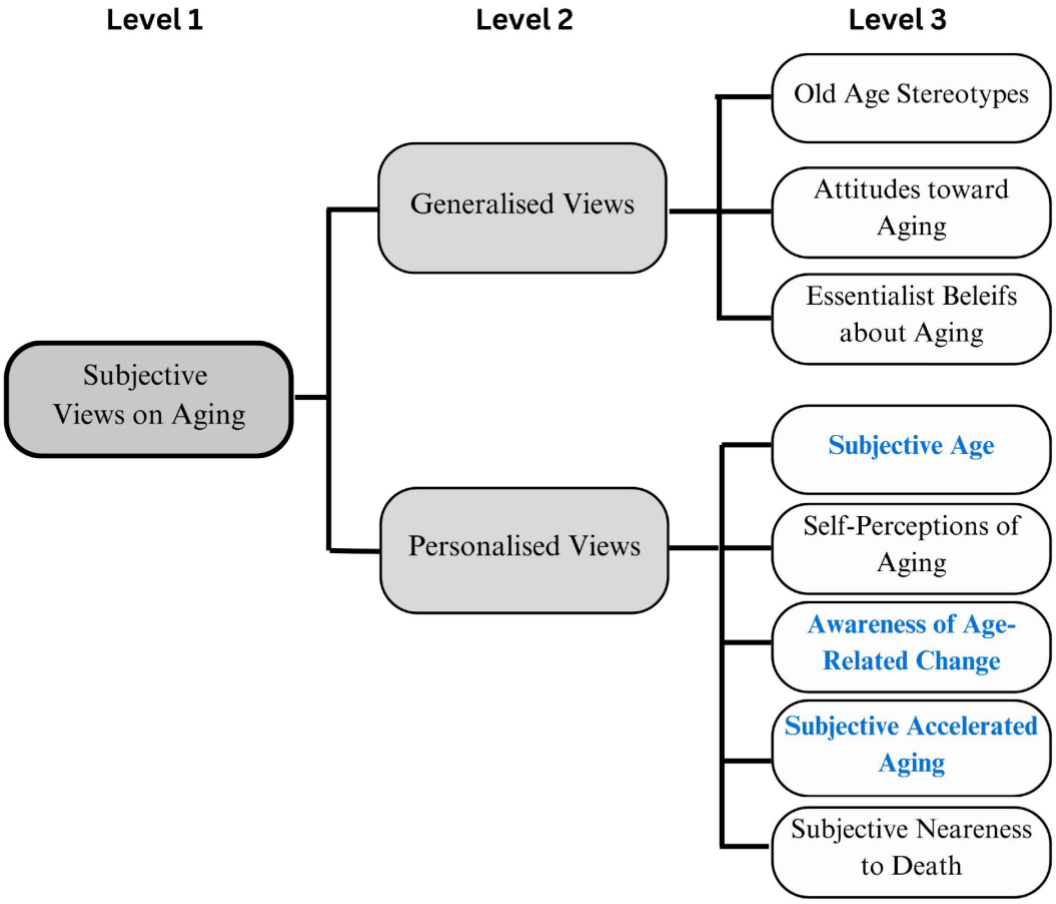

Figure 1.1. A conceptual hierarchy of subjective Views of Aging. Constructs in blue represent those included in the current thesis. Adapted from (Shrira et al., 2022).

Personalized Views of Aging

Subjective Age

Subjective age refers to how old individuals feel compared to their chronological age (Kastenbaum et al., 1972). In fact, people's felt age increases more slowly than their chronological age, as people feel two-thirds of a year older for each year lived (Kotter-Grühn

et al., 2009). Subjective age is considered multidimensional, multifunctional, and multidirectional and an essential part of people's age identity.

The multidimensionality of subjective age (Kastenbaum et al., 1972; Kornadt et al., 2018), which is reflected in the hierarchy presented in Figure 1.2, encompasses various ways in which people feel about their age. Several dimensions of subjective age have been suggested, such as felt age, which refers to how old a person feels emotionally; ideal age, which is how old one wishes to be; look age, which describes how old one estimates their physical appearance; and do-age, which indicates how old a person perceives their behavior to be (Kastenbaum et al., 1972; Montepare, 2009). To account for the multidimensionality of subjective age, a scale has been developed to capture its dimensions (Barak & Stern, 1986), which include psychological health, physical health, physical appearance, and behavior. Relatedly, subjective age has been shown to be domain-specific (Kornadt & Rothermund, 2011, 2015). Studies have demonstrated that people's perceptions of subjective age vary if they are primed with different life domains. For example, health, work, and social domains seem especially relevant to subjective aging perceptions (Hess et al., 2017).

Concerning multifunctionality, it has been suggested that subjective age can serve as a protective mechanism, protecting the individual from negative age stereotypes and ageism. First, feeling younger can provide emotional comfort. For example, as individuals face negative health events, feeling younger may offer emotional comfort and a buffer against stress and anxiety associated with the health issues (Hughes & Touron, 2021). A younger subjective age can also help individuals psychologically distance themselves in the face of negative age stereotypes and other social beliefs about aging. Such distancing from an old-age group may protect people's self-esteem and lead to better life satisfaction (Grah et al., 2018). Second, subjective age has been shown to increase motivation for making positive lifestyle choices (Montepare, 2020). People who feel younger are more likely to participate in health-promoting behaviors and pursue social connections, which are essential for well-being.

Finally, subjective age is considered multidirectional (Kornadt et al., 2020). In relation to domains, people may feel older in one domain (mental health) and at the same time younger in another (physical health). Furthermore, in line with the aims of this thesis, directionality can also exist in temporal aspects, which can go in different directions with time: one may feel older in a period with elevated stress and then younger when the stressful period has ended. Such temporal changes are likely to be influenced by contextual variations.

Although subjective age is considered a multidimensional phenomenon, most studies have measured subjective age as a single item, asking people how old they feel compared to their chronological age. Looking at overall aging, this is an efficient and economic measure for researchers. The scores represent a numerical value indicating the age at which people feel. This has often been operationalized either as difference scores (subjective age – chronological age) or as proportional difference scores ((subjective age-chronological age)/chronological age). These different operationalizations reveal distinct patterns throughout life (Cohn-Schwartz & Gerstorf, 2022; Pinquart & Wahl, 2021), as shown below in Figure 2. Difference scores show a linear trend for adults, indicating that people feel increasingly younger than their chronological age. Proportional difference scores show that the proportional difference between how old people is and how old they feel flattens at higher chronological ages. Proportional difference scores are the most used in studies with bigger age ranges as they facilitate cross-cohort comparison.

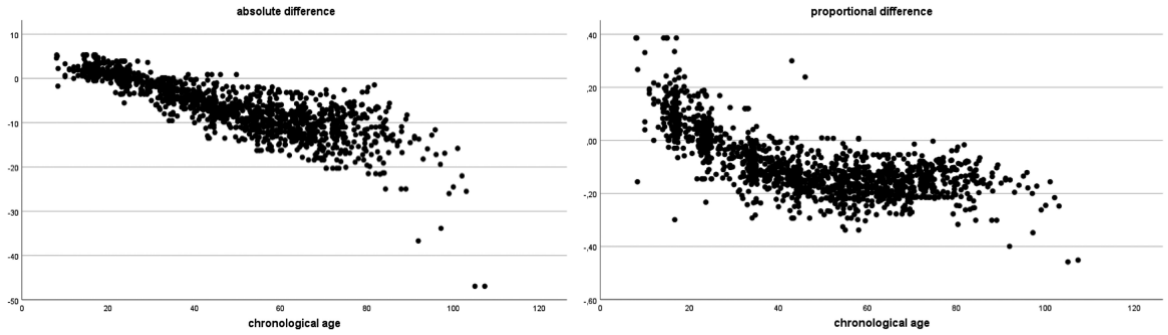

Figure 2. Left: discrepancy scores of subjective age of adults across adult chronological age. Right: proportional difference scores of subjective age mapped across adult chronological age (Pinquart & Wahl, 2021).

Awareness of Age-Related Changes

Awareness of age-related changes (AARC) refers to people's reflections on and awareness of personal changes caused by growing older (Diehl & Wahl, 2009). These changes may be in performance levels, behaviors, and ways of experiencing life. It is important to note that people must attribute the changes in their constitution to increased chronological age and not to changes in other factors, such as health status. The authors suggest that AARC, like subjective age, can be domain-dependent: physical functioning, cognitive functioning, interpersonal relationships, lifestyle and engagement, and social-cognitive and social-emotional functioning. From this perspective, AARC losses can signify developmental limitations on an individual's behavior and experiences. In contrast, recognizing AARC gains can highlight developmental opportunities, encouraging positive behaviors (Diehl et al., 2015). Furthermore, studies have found that people tend to start noticing fewer ongoing developments at around the age of 55, whereas AARC losses have been found to set in at the age of 65 for physical and social losses (Diehl et al., 2021). These findings speak for the fact that events and experiences at a certain age are more likely to activate or affect one's views of aging.

In the context of this thesis, the AARC is particularly interesting as it focuses on experiences of daily life that lead to people's subjective age (Brothers et al., 2016; Diehl et al., 2015). AARC has indeed been found to fluctuate across days (Neupert & Bellingtier, 2017). The AARC concept itself speaks for within-person variability in people's views of aging as it measures several positive and negative experiences of aging. Views of aging, including AARC, are thought to also reflect psychological mechanisms that account for,

adaptations to health challenges in later life (Shrira et al., 2022). This has further led to views of aging being seen not merely as predictors, but also as potential moderators and mediators of other factors. Additionally, AARC offers a multidimensional perspective on views of aging which may give further insights into the mechanisms at play when people construe their views of aging. Including AARC as a moderator on the association between predictors and views of aging outcomes, may reveal how different views of aging facets contribute to their overall views of aging.

Subjective Accelerated Aging

Subjective accelerated aging is a new but nevertheless important construct as it continues the concept of change articulated by AARC. Subjective accelerated aging describes how quickly people experience their aging speed, categorizing it as slow, normal, or accelerated (Palgi, 2020). Subjective accelerated aging arises from the idea of the weathering hypothesis stating that repeated stress exposure leads to an accelerated aging process (Geronimus, 1996), and the observations that significant stressors can lead to both biological- (Tsur et al., 2018) and subjective/psychological aging (Avidor et al., 2014). So far, there are less than a handful of studies looking at subjective accelerated aging. Elevated subjective accelerated aging is associated with more mental distress (Palgi, 2020), and to moderate the effect of COVID-19 health worries on peritraumatic distress, as it was associated with a reinforced effect of more COVID-19 health worries with increased peritraumatic distress (Greenblatt-Kimron et al., 2021).

These three views of aging constructs constitute different aspects of the subjective aging experience. Subjective age is the most frequently studied of the three and, therefore, often guides research on the others. AARC represents an effort to account for subjective aging as both a positive and a negative experience. AARC goes further into people's views of aging by examining specific experiences that underlie the aging experience. Subjective accelerated ,

aging places a stronger emphasis on the perception of the process of aging itself rather than focusing on the temporal distance to specific events. Like the AARC construct, it highlights adults' recognition of the personal changes brought about by aging but less concretely linked to specific experiences. As will be demonstrated in Chapter 3 of this thesis, the intercorrelations between views of aging measures are generally modest, speaking for the fact that views of aging are multidimensional and, therefore, represent different aspects of the aging experience (Kornadt et al., 2020). Here lies the motivation for the views of aging measures included in this work. Traditional subjective age measures offer a simpler comparison to previous studies; AARC provides a more nuanced perspective on the aging process, incorporating different domains and facets, while accelerated aging, as the newest construct, provides an alternative perspective by focusing on the temporal aspect of how people perceive their aging process.

Developmental Trajectories of Views of Aging

As aging is an ongoing process, views of aging should be viewed through a lifespan developmental lens to comprehend its origins and the changes it undergoes with time. Therefore, several theoretical frameworks and ideas on how subjective aging occurs throughout life have been proposed (Barrett & Montepare, 2015; Kornadt et al., 2020), suggesting how views of aging change across life. Generally, views of aging should be regarded as both drivers and products of development. First, views of aging have demonstrated impacts on several aspects of successful development, including health and mortality (Westerhof et al., 2023; Wurm et al., 2017), cognitive functioning (Siebert et al., 2018) as well as social functioning (Menkin et al., 2017). Second, individuals' views of aging are shaped by their lifelong development, which influences their understanding of what aging entails and what it means to be old across different life domains. This circular process is likely influenced by the societal context, individual expectations, motivation, history, present

circumstances, and future possibilities, along with their available resources This process also takes place within an individual's particular historical and cultural setting, providing a macro context. The framework by Kornadt et al. (2020) underscores that views of aging are multidimensional, multidirectional, and context-dependent and that they are shaped by both micro and macro-level processes. The authors further emphasize that to understand these processes and people's views of aging as their outcome, we must consider views of aging within different time frames.

More specifically, people may construe their views of aging based on processes of anchoring and adjusting it to distal and proximal reference points throughout life (Montepare, 2009). Distal reference points are stable and internal beliefs about aging and development, such as the expectation of having grandchildren at a certain age. These distal reference points serve as age markers to which people are assumed to compare themselves. Proximal reference points are events that are personal and age-symbolic. These events can be historical, physical, or interpersonal age markers, such as having grandchildren, experiencing specific health problems, or retiring. According to this theory, people aim to reach and maintain desirable life stages: teenagers and young adults will associate getting older with more positive outcomes (becoming of age, independent, graduating) and, therefore, feeling older. As people get older, they will expect more negative sides of growing older and may, therefore, start to feel younger in an effort to remain associated with the younger age groups. With most distal and proximal age markers being outlived, we expect that subjective age will stabilize in the oldest ages. In addition to framing the developmental pattern of subjective aging, this theory also suggests that by looking at shorter time periods, we will learn how event-related events (proximal reference points) influence subjective aging. If we study how proximal, personal events impact people's subjective age, we may find other characteristics and fluctuations in people's subjective ages.

Similarly, Stereotype embodiment theory (Levy, 2009) helps us understand how cultural forces and personal perceptions together inform views of aging. This theory suggests that individuals integrate stereotypes about old age (what is an old person and what older people should be like) early in life and apply them to the self as they age, as they gain more salience by becoming self-relevant. From this perspective, views of aging are social constructs of social-cognitive mechanisms that may work both consciously and unconsciously. Age stereotypes may be both part of one generalized and personalized view of aging (Figure 1.1) (Shrira et al., 2022). At the generalized level, views of aging, including age stereotypes, are believed to function subconsciously, influenced by cultural norms, expectations, and societal views of aging. These cultural images are internalized by comparing one's own aging to these culturally informed age stereotypes. At this point, the stereotypes are a part of the individual's personal views of aging, meaning that they operate predominantly on a conscious level as people are aware of and likely reflect upon them. From a lifespan perspective, age stereotypes are expected to be internalized from a young age and throughout life. Older people may apply these to themselves and assimilate their self-views with these stereotypes. On the other hand, people may also dissociate or distance themselves from negative age stereotypes (Weiss & Kornadt, 2018). We can expect such dissociation processes to become more frequent as people become older, and age stereotypes apply to them more frequently than at younger ages.

Furthermore, Levy (2009) proposes three pathways for which age stereotypes can affect developmental outcomes: a physiological, a psychological, and a behavioral pathway. The psychological pathway suggests that people's expectations may work as self-fulfilling prophecies, as people expect aging and old age to be a certain way. The behavioral pathway suggests that people's beliefs about aging may influence how they behave: holding more essentialist beliefs, such as "health problems are inevitable at older ages", may lead people to neglect health-promoting practices and grooming behavior. Finally, the physiological

pathway is based on findings that have linked negative age stereotypes to increased cardiovascular responses to stress, suggesting placebo/nocebo effects. Age stereotypes have been shown to influence self-perceptions, making it possible that views of aging may also be influenced via similar pathways. These pathways may also be subject to anchoring and adjustment processes like those proposed by Montepare (2009). In sum, early life experiences and expectations influence people's views of aging as they grow older. People have expectations about what old age means regarding distal reference points and stereotypes, which will become increasingly self-relevant as they grow older. These influences may additionally operate through different pathways when asserting their effect on people's views of aging. This also frames how general views of aging become personal views of aging as people get older, indicating that people's views of aging will fluctuate across the lifespan.

Taking a related perspective, which builds on SET, Weiss and Weiss (2019) have composed a framework stating that people have cognitive working models of aging, which are informed by their social-cognitive representations. These representations encompass not only age stereotypes, but also personal experiences of aging and beliefs related to aging. Individuals compare themselves to their past and future selves, experiencing or anticipating changes, or the lack thereof, which shapes their views of aging. Whether people feel younger or older also depends on their motivation to approach or avoid certain ages or age groups with the goal of enhancing or protecting the self. This perspective further highlights how views of aging can relate to people's cognitions, self-evaluations, and societal expectations, demonstrating that both internal and external factors influence people's views of aging.

Taking a life course perspective on views of aging Barrett and Montepare (2015) points to principles for comprehending subjective processes, whereof one is the importance of historical time. This emphasizes the necessity to understand subjective aging processes happening within- and due to historical contexts. Especially relevant for the period of this thesis has been the COVID-19 pandemic, which provided a unique context that spotlighted

older people as it made age, age stereotypes, and the health of older people a prominent societal focus. A single study cannot account for the long-term effects of such a special historical event that may cause life stage-, life course-, and possible cohort differences.

With the aim of combining these theoretical perspectives and acknowledging the broad spectrum of views of aging, *'The Multidimensional, Multitemporal and Ecological Framework'* (MMEF) has been proposed (Shrira et al., 2022). This framework underscores, as demonstrated previously, that views of aging are multidimensional and consist of both generalized and personalized views of aging. Especially useful in the context of the present thesis are the multitemporal and ecological aspects. The ecological aspect refers to the role of context in shaping views of aging, including societal, cultural, and situational factors. Multitemporal refers to the dynamic aspect of views of aging, indicating that views of aging can show different characteristics depending on the timeframe considered. We need to look at how people perceive their aging process in and across different life periods and associated environmental or situational factors. Similarly to Montepare's and Levy's theoretical frameworks, the MMEF acknowledges that external factors such as place of living, historical context, and physical context influence one's views of aging. In addition, it highlights that people's interpersonal processes also significantly shape their views of aging. To conclude, these theories help us understand how views of aging develop across the lifespan and the possible sources and pathways of these processes. These lifespan perspectives indicate that there is a stable, predictable pattern of views of aging, but that people update their views of aging throughout life in relation to specific events. Finally, these theoretical perspectives demonstrate how views of aging may operate as a link between psychological, biological, and social aging.

Empirical Findings

Research results endorse many of the theoretical proposals outlined earlier regarding the lifespan development of views of aging. For example, subjective age shows a distinct pattern throughout life. Younger individuals often perceive themselves to be older than their actual age, but around the age of 30, this perception shifts, and they begin to feel younger than their chronological age (Pinquart & Wahl, 2021). As demonstrated, looking at proportional difference scores, the difference between chronological age and subjective age increases from young adulthood to midlife and then remains stable. Relatedly, awareness of age-related losses has been shown to set in around the age of 65 for physical and social losses, while people notice fewer ongoing developments from around age 55 (Diehl et al., 2021), providing support for theories suggesting that age-related perceptions of the self will become more prominent with self-relevance.

Understanding how subjective aging develops throughout the lifespan is crucial, as subjective age relates to various developmental outcomes over time (Pinquart & Wahl, 2021). Factors in adolescence and younger people have been related to subjective age in older age. For example, high school students with higher intelligence scores felt younger in their old age, demonstrating that early-life cognitive abilities impact subjective aging later in life (Stephan, Sutin, Kornadt, et al., 2018).

The disparity between subjective age and chronological age appears to be a universal phenomenon as it is observed across continents. The differences are bigger in Western Europe and America and smaller in Africa (Anton Schönstein et al., 2021). These differences are associated with factors such as individualist-collectivist societies, social power distance, preference for younger adults, and the quality of life for older adults. This supports the idea that feeling younger than one's age is a general trend across cultures, but the extent of the gap appears to be affected by factors related to culture, values, and health (Pinquart & Wahl, 2021). Overall, the findings discussed above indicate that the relative stability of subjective

age throughout adulthood has led to it being viewed as a trait-like construct that reflects part of individuals' identities as they navigate through life.

People's views of aging also fluctuate over longer time scales, such as decades, years, and months, as stipulated in the MMEF. Longitudinal studies have demonstrated the effects of and on views of aging constructs. For instance, older adults who indicated an older subjective age were likelier to exhibit poorer cognition a decade later (Qiao et al., 2021). Although the opposite direction effects are less often examined, studies do show this direction of influence. For example, it has been shown that better physical and mental health, along with higher personal mastery, predicted a younger subjective age five years later (Bergland et al., 2014), and these effects varied across age groups: for people aged 40-49 high personal mastery and good health predicted a younger subjective age, for those aged 60-69 only personal mastery was associated with feeling younger, and finally, for those aged 70-79 better mental and physical health was associated with feeling younger.

There are fewer studies on bidirectional effects between views of aging and other factors. A study examining the bidirectional association between subjective age and health measures found an effect of subjective age on ADL limitations and depressive symptoms, but not in the opposite direction (Rippon & Steptoe, 2018). Another study on association between health measures and subjective age found longitudinal association where subjective age predicted physical, mental and self-rated health, whereas only self-rated health was found to be associated with longitudinal changes in subjective age (Spuling et al., 2013). Other efforts have been made in cross-lagged models. One such study demonstrated that an initial older subjective age predicted frailty, but the reverse effect was non-significant (Li et al., 2021). One study demonstrated an effect of health measures on subjective age as more PTSD symptoms predicted an older subjective age a year later (Palgi et al., 2019). In sum, the effect of subjective age on diverse developmental and health outcomes has been rather well

documented, whereas the effects in the opposite direction have proven more difficult to unravel. Therefore, the drivers and dynamics of views of aging remain under-explored.

Yet some factors are shown to cause fluctuations in views of aging over time. Fluctuations in subjective aging can be caused by, for example, different stress factors such as turbulence within one's family and health or social comparisons (Schafer & Shippee, 2010). Hughes and Lachman (2016) found fluctuations in subjective age over 10 years, as people's social comparisons of their memory and health mediated the effects of memory performance- and functional health performance on subjective age, supporting the idea that views of aging are based on social-cognitive mechanisms (Weiss & Weiss, 2019). Additionally, views of aging are domain-dependent, as people have found to feel younger in domains where age stereotypes are more common, like health, work, or finances, compared to domains of family, leisure, and friends (Kornadt et al., 2018). Finally, specific events have been shown to generate shifts in people's subjective age, as people feel older closer to their birthday (Montepare, 1996). In sum, views of aging show fluctuations over longer periods, such as decades and years, speaking for both trait characteristics and malleability/plasticity in how people perceive their aging process.

Zooming in: Short-Term and Intraindividual Variations in Views of Aging

Views of aging show long-term trajectories, as demonstrated above, but can also vary over shorter time scales. Certain days or weeks can reflect declining health and increased limitations, whereas other periods may signify gains and growth for older adults. For example, older people may feel older in the morning after a bad night of sleep or energetic and younger after reconnecting with a friend from college. Proximal reference points, as outlined above, may also represent not only highly age-significant events but also subtle age-related situations in people's daily lives. To fully understand the aging experience, we must grasp the importance of short-term variations in people's views of aging. Insights into

predictors of these fluctuations may inform underlying mechanisms and processes of the aging experience. Understanding the outcomes of these variations can help us comprehend the mechanisms of subjective aging, leading to improved aging outcomes.

Recent theoretical perspectives emphasize the importance of incorporating short-term fluctuations and their influences into our study of views of aging. The MMEF indicates that perceptions of aging exhibit both long-term and short-term fluctuations, reflecting that views of aging have both trait and state aspects. Distal and proximal reference points further suggest that qualitatively different life contexts relate differently to how people construe their views of aging. Views of aging constitute a dynamic construct that responds to processes within the individual and their environment. People encounter many situations throughout and across days that make their age more salient. Interested in how everyday personal events impact the aging identity process, Hughes and Touron (2021) have proposed a specific contextual model of subjective aging. The model allows us to recognize the state of an individual's views of aging, as it illustrates how contextual cognitive and physical challenges, along with social and environmental factors, shape people's views of aging. This model is an extension of the framework of Montepare (2009), as it shows that general expectations and developmental roles (which impact the lifespan context) again influence the immediate context and how people construe their views of aging at a certain moment in time.

Relatedly, Weiss and Weiss (2019) propose two primary mechanisms to explain why people feel younger. In short, they argue that individuals maintain a working model of aging shaped by their social-cognitive age representations. These representations encompass personal aging experiences, age stereotypes, and ageist beliefs. Importantly, shifts in people's views of aging and subjective age are regarded as the outcome of two comparison processes. First, individuals reflect on their personal changes by comparing their current selves to their former and future selves. In a daily life context, an older person may recognize that it is getting heavier to carry one's groceries than it was last month or even the day before. Second,

they compare themselves with age stereotypes, considering what older people are typically like. The same person carrying their groceries may think that one's carrying capacity is reduced to such an extent that this is at the level of older people.

In summary, theoretical developments have provided a framework for how we may understand short-term fluctuations in views of aging. The contextual model underscores the important influence of considering proximal contexts that likely influence views of aging in a given day or moment. More specifically, the working model of aging theory goes further by demonstrating possible mechanisms for fluctuations in people's views of aging, including comparison processes, motivation, and social-cognitive age representations. These models provide a framework for studying short-term fluctuations of views of aging, possible drivers, and mechanisms.

Empirical Findings

Overall, findings from studies on short-term variations in views of aging underscore theoretical assumptions of the MMEF. As stated by Cohn-Schwartz and Gerstorf (2022) and akin to the MMEF, subjective age is a component of the core self-concept that possesses both stable and flexible aspects, shaped by the immediate context and situation in which people find themselves. Thus, both theory and studies suggest that individuals may experience significant fluctuations within a day as well as across days, depending on the situation, which speaks for views of aging as multi-dimensional and multidirectional.

Beyond theoretical elaborations, views of aging have indeed been shown to vary on shorter timescales in empirical studies. Experimental studies reveal that views of aging can be manipulated in the laboratory setting. For example, Stephan et al. (2013) demonstrated how subjective age is associated with physical factors. The researchers found that older adults who received positive feedback on a handgrip strength test reported younger subjective ages compared to controls, which further led to better performances on a second handgrip test.

Another example is Eibach et al. (2010) who managed to induce an older subjective age by giving older people a visual disfluency test. Individuals informed that the blurry text was a printing error felt on average, younger than those who were not given any information about the blurriness of the text. Experimental studies thus suggest that views of aging can fluctuate due to the immediate context associated with it, e.g., physical performance, cognition, and social comparison.

Yet, experimental studies are limited in the ecological information they provide. Aging happens in daily life as older people go about their day. It is in daily life where people likely encounter diverse situations that remind them or make them aware of their own aging. For example, a person who used to enjoy driving at night may find that his night vision has deteriorated, and night driving has become a hazard. Alternatively, performing physical activities may become more strenuous, and a person may feel older due to realizing this. The importance of studying views of aging in real life has been demonstrated in a study that established an association between subjective age and walking speed in the laboratory but not in a real-life setting (Notthoff et al., 2018).

Advancements in technology and methods facilitate studying aging as people go on with their daily lives through daily diary studies and ecological experience sampling (also known as ambulatory assessment studies). This type of study allows for examining intra- and inter-personal fluctuations over more fine-grained timescales as it offers the opportunity for repeated measures. Such methods extend our knowledge from experimental studies, allowing us to investigate the temporal length of the effect of proximal age markers and age salient contexts.

Indeed, studies using intensive ecological assessment methods have provided evidence that views of aging have significant within- and between-person fluctuations over shorter timespans. O'Brien and Smyth (2023) measured daily variation in several views of aging measures in older adults over a week. They found that there is notable within-person variation

across days (from 8-38%, depending on the views of aging measure), although the between-person variation accounted for the greatest percentage (at least 62%). They also found age differences that inform lifespan perspectives: older people showed, on average, less intraindividual variation compared to younger adults, who demonstrated the highest average intraclass correlation (ICC: a higher ICC score is associated with more variance on the between-person level, whereas a lower score is associated with more variance on the within-person level). Their results showed similar trends and differences in ICC scores depending on the views of aging measure. In general, this corresponds with other daily diary studies that reveal considerable within-person daily fluctuations in subjective aging measures, ranging from 19% to 44% (Armenta et al., 2018; Cohn-Schwartz & Gerstorf, 2022; Kotter-Grühn et al., 2015; Neupert & Bellingtier, 2017; Neupert & Bellingtier, 2022; Schmidt et al., 2024). For example, Schmidt et al. (2024) found that as much as 44% of the total variation in subjective age was due to intraindividual variation. They further demonstrated how affect was a major influence of this variation, followed by stress and steps. On days with more positive emotions, lower levels of stress and more steps, people felt younger. Other studies have also shown how daily fluctuations are associated with contextual factors such as people's sense of control (Bellingtier & Neupert, 2019), daily stressors, health problems, and negative affect (Kotter-Grühn et al., 2015).

On even shorter time scales, views of aging have been found to fluctuate within days. Momentary within-person variation in subjective age has been shown to be as high as 25% in older people, with individual felt ages fluctuating as much as 3 years from one moment to the next (Kornadt et al., 2021). Interestingly and in contrast to what was found on the daily level (O'Brien & Smyth, 2023), this variation was not associated with chronological age but with trait subjective age: individuals with a younger trait subjective age exhibited larger variation in their momentary reports. This demonstrates the importance of investigating different timelines of the views of aging constructs. Drivers of momentary fluctuations in views of

aging are yet to be revealed, demonstrating that there are gaps in the current literature. To my knowledge, there is until now only an established association between perceived and physiological stress and fluctuations in momentary subjective age (Kornadt et al., 2022).

This section has displayed how studying views of aging through timelines each provides its unique contribution. Long-term approaches have provided evidence for developmental processes and life-stage conditions that influence how well people age, speaking for trait-like aspects and long-term fluctuations. Experimental studies have provided insights into how views of aging can also be malleable by contextual manipulation. Studying short-term dynamics over months, days, and even moments offers the opportunity to further investigate the underlying mechanisms of what makes people feel older or younger, an area of far less knowledge. Firstly, with longitudinal studies that focus on a specific period, we may further understand how views of aging fluctuate over months and the impact of both the timeline and the broader context. Daily studies thus far have demonstrated that individuals vary between days and have related this to behavioral- and cognitive factors. Therefore, studies focusing on daily (intraindividual) variations are particularly suited to connect views of aging with factors that also fluctuate over similar timescales, such as sleep quality, physical activity, physical health issues, and mental states. Finally, studies on within-day or momentary fluctuations are especially interesting for exploring views of aging and the immediate context. In this timescale, we can gain insights into how views of aging fluctuate in response to immediate factors like physiological measures (stress, heart rate) and subjective experiences (emotional reactions, pain sensations) and how they relate to the surrounding context, providing a more detailed picture of how views of aging fluctuate in response to the immediate context.

1.3 Views of Aging – Shaping and Driving Factors

Various factors likely shape people's views of aging and identifying the dynamics that contribute to older or younger age identities is crucial. Such knowledge will enhance our understanding of what constitutes "normal and abnormal" psychological aging. Furthermore, views of aging often predict physical, psychological, and social outcomes more accurately than factors like education or physical conditions (Wurm et al., 2017), and so insights into the constructions of views of aging will improve our understanding of these associations. Overall, there is great potential for revealing mechanisms that lead to better aging outcomes and for creating targeted interventions as a result.

As previously demonstrated, views of aging have multidimensional- and domain-specific characteristics (Kastenbaum et al., 1972; Kornadt et al., 2018) and likely evolve due to dynamic and continuous interactions between biological, psychological, and social contextual factors (Kornadt et al., 2020). Biological factors can be related to physiological and physical aspects such as pain, or symptom load, psychological factors to people's feelings, thoughts, and reflections, and social factors such as the presence of others, socially shared beliefs about aging.

Drawing again on stereotype embodiment theory, (Levy, 2009) we can more concretely carve out some expectations about what influences views of aging and possible mechanisms. SET suggests that there is a psychological, physical, and behavioral pathway for which age stereotypes influence developmental outcomes. Such outcomes include self-perceptions of aging, as age stereotypes have been shown to have a bidirectional association with self-views (Rothermund & Brandtstädter, 2003). Based on this theory and findings, as well as the findings that views of aging are multidimensional, it is reasonable to assume that drivers of views of aging will also be represented by these categories.

Stereotype embodiment theory allows for more concrete stipulations of how these factors may influence views of aging. The psychological pathway suggests that people's

expectations about what a certain age contains will influence their development and performance. For example, believing that older people have memory problems can reduce their performance on cognitive tasks, making such beliefs self-fulfilling prophecies. The physiological pathway suggests that aging is associated with physiological responses such as stress. Factors that increase such physiological responses, such as psychological and cognitive stress, may operate through this path to assert their influence.

Some factors are shown to be associated with interpersonal views of aging. For example, better health, personal mastery, control beliefs, and activities of daily living predict younger subjective age (Barak & Stern, 1986; Bellingtier & Neupert, 2019; Bergland et al., 2014; Markides & Boldt, 1983; Rubin & Berntsen, 2006). The literature is narrower regarding factors driving intrapersonal changes in views of aging.,

In the coming sections, I will introduce the factors under investigation in the current thesis. These factors have been chosen with the aim of exploring psychological, behavioral as well as possible physical factors. With AARC already presented above, I will in the following present health, pain, physical activity, and psychological factors in terms of worries and cognitive evaluations as possible factors influencing people's views of aging.

Health: An Important Connection

In line with the idea that biological factors play a role in views of aging, and that there may be a physiological pathway influencing people's views of aging, researchers have been interested in how different health measures relate to views of aging. There is indeed a well-established longitudinal link between views of aging and health outcomes (Westerhof et al., 2023). While there are effects of some health factors on views of aging, other health factors need further exploration (Spuling et al., 2013). From a contextual perspective, negative health events and health changes might be seen as bodily reminders of age, as worse health is

associated with older ages by most people (Barrett & Gumber, 2020). Alternatively, decreasing health may reduce the resources that people have available to cope with other age-related changes, which may further deteriorate their views of aging. For example, Wurm et al. (2020) found that experiencing a cardiovascular event was longitudinally associated with worse scores on views of aging constructs. In light of the theory of anchoring and adjustment, (Montepare, 2009) health changes may represent both distal and proximal events, making people adjust their views of aging according to their changed situation. In this regard, people who have fewer experiences with negative health events and conditions will likely feel younger both because they did not have anchoring and adjustment needs and secondly because they simply have fewer negative sensations and more positive ones when making physical efforts as in their daily lives.

Empirically, there is some evidence for the directional effect of health informing views of aging. This effect is especially important because better health is increasingly related to feeling younger as people get chronologically older (Stephan et al., 2012). For instance, longitudinal associations show that functional health may interact with cognitive factors in influencing subjective age (Hughes & Lachman, 2016). However, the association of health factors with views of aging seems to be somewhat dependent on both the specific health measures, views of aging domains, as well as age and gender (Hubley & Russell, 2009). Relatedly, Kim et al. (2021) found within-person associations across 8 years between health (chronic conditions in men and functional health in women) and views of aging. Others interested in health and views of aging have, for example, demonstrated associations between biological markers of health and views of aging: lower C-reactive protein, a biomarker of kidney function, is associated with a younger subjective age 4 years later (Stephan et al., 2017). Longitudinal studies speak for an effect where better health is associated with more positive outcomes of views of aging, such as feeling younger. Studies on the effect of health on views of aging in more narrow timelines are limited. Some daily diary studies have

demonstrated that on days with fewer than average health problems, people felt younger (Bellingtier et al., 2017; Kotter-Grühn et al., 2015). The effect of health measures on views of aging seems to depend on the type of health measures, and there is currently a gap in the literature providing information on the associations over shorter timeframes.

Health may further provide a context for the association between views of aging and other factors, as health represents a domain of negative age stereotypes (Hess et al., 2017). In addition, representing either proximal or distal age markers, health may operate as a moderating context for which other drivers assert their influence on views of aging. For example, as people experience more pain (which is assumed to make people feel older), having worse health may exacerbate the negative effect of pain on views of aging, making people feel worse about their own aging. In conclusion, health seems to be related to views of aging as both an outcome, a predictor, and a moderator, where the last two seem to need further explorations.

The Significant Role of Pain

In addition to more general aspects of health and health changes, pain is one bodily-related variable of special importance for views of aging (Barrett & Gumber, 2020; Goecke & Kunze, 2020; Kotter-Grühn et al., 2015; Wettstein et al., 2024). As pain is a common condition in the second half of life and is often not sufficiently treated (Miaskowski et al., 2020), there seems to be a general misconception that pain is an inevitable part of aging. Pain in middle and later adulthood may be interpreted as a sign of aging, making people feel older. Firstly, pain may function as a body reminder of aging (Barrett & Gumber, 2020) as individuals have been found to feel older on days in which they experience more pain (Goecke & Kunze, 2020). Second, pain may represent an age-salient context (Hughes & Touron, 2021), and, therefore, influence short-term fluctuation of views of aging in daily life. Pain can represent an immediate (within-person) context that informs people while

constructing their views of aging. Cross-sectionally, more pain has been shown to be associated with feeling older (Booker et al., 2020). Pain has also cross-sectionally been related to other views of aging constructs such as AARC losses, but not AARC gains (Sabatini et al., 2021).

Over longitudinal timeframes, more pain has been found to be associated with older subjective ages. For example, rheumatism (which usually includes pain), has been found to predict an older subjective age in older people, 7 years later (A. Schönstein et al., 2021). In addition to the study above, Kotter-Grühn et al. (2015) have demonstrated people felt older on days in which they experienced more pain. However, it remains to be examined whether the association between pain and views of aging also exists on a within-day level. Revealing such couplings on a scale within days is relevant for understanding how immediate contexts that can lead to, for example older subjective ages, further lead to negative lifestyle choices. Waking up to pain may remind a person of their age and activate related age beliefs and stereotypes, this may again lead them to believe that the pain is a part of growing older and not search for remedies that may reduce his pain. Over time, this line of effects may, for example lead to worse health and lower well-being. Such information can be applied to reduce or promote factors in daily life that can contribute to a higher quality of life for older people (Hughes & Touron, 2021).

Physical Activity

Another factor related to views of aging is physical activity. Physical activity may influence views of aging through several mechanisms. Theoretically, physical activity may operate through a physiological pathway as stated in the stereotype embodiment theory. Physiological processes associated with physical activity, such as improved circulation and increased mobility, may lead to a more positive outlook on aging. In light of the working-models of aging by (Weiss & Weiss, 2019), individuals might compare themselves to others

based on their beliefs about the capabilities of their age group regarding physical activity. Finally, physical activity, even at low levels, likely boosts older individuals' sense of control and improves their mood, which are both associated with feeling younger (Bellingtier et al., 2021; Kotter-Grühn et al., 2015).

Few studies have so far investigated the effect of physical activity on subjective age, but Stephan et al. (2020) have demonstrated that physical activity influences subjective age over a period of 8 to 20 years. They found that more activity at baseline was associated with feeling younger at follow-up. Interestingly, they also found an indirect effect through self-rated health, reinforcing this association. Another interesting study is an intervention study that looked at how an exercise intervention program, including an intervention targeting self-perception of aging, could alter people's self-perception of aging (Beyer et al., 2019). Participants were divided into two groups, one with only an exercise intervention program, and the other which also included a psychological intervention targeted at self-perceptions of aging. Their results demonstrated that both groups had improvements in their physical performance, whereas only the intervention group had changes in their self-perceptions of aging. With such diverse findings, the effect of physical activity on subjective age remains uncertain.

As previously stated, objective and ecological assessments may be crucial for further revealing these associations in a real-life setting, as long-term longitudinal and experimental findings do not alone allow for general conclusions (Notthoff et al., 2018). With momentary ecological assessment studies, we can measure not only views of aging as people go on about their daily lives but also correlate this to objective measures of what people are actually doing in the moments previously. These methods do not only reduce recollection bias but also allow us to measure the constructs of interest consecutively. Chapter 4 of this thesis looks at momentary, objective measures of people's momentary physical activity and its relation to their subjective age.

How Psychological Factors May Influence Views of Aging

Views of aging are associated with many psychological factors. Montepare's distal and proximal reference points demonstrate how people's expectations and thoughts about aging and their own age lead to the construction of their age identity through life. Furthermore, the cognitive working model of aging suggests that several psychological processes may be at play to influence people's views of aging. The working model of aging states that people's views of aging are a result of information-processing and therefore related to people's cognitive processes. Additionally, stereotype embodiment theory highlights the psychological aspect of people's views of aging: stereotypes are believed to influence people's views of aging through the three pathways, indicating that psychological factors may have a strong influence on people's views of aging.

Empirically, most studies have demonstrated effects of views of aging constructs on psychological outcomes (Alonso Debreczeni & Bailey, 2020; Mock & Eibach, 2011). Although there is a gap in the literature on psychological predictors of views of aging, there are a few studies to draw from. For example, better mental health and personal mastery have been found to be associated with feeling younger (Bergland et al., 2014; Hubley & Russell, 2009), and negative affect has been associated with daily within-person variations of subjective age.

Chapter 3 of this thesis investigates the interplay between views of aging and older people's emotions and cognitions. The manuscript demonstrates how cognitions and emotions of older people, related to the pandemic, influenced their views of aging over several months.

1.4 Aims of the Thesis

Views of aging are related to and predict many important developmental outcomes in the second half of life. Yet, less is known about how people construe their views of aging and underlying mechanisms. Theoretical and literature review manuscripts have pointed to a need to study views of aging through the scope of different time perspectives (Cohn-Schwartz & Gerstorf, 2022). Varying timelines can inform us about how changing contexts influence people's views of aging. Fluctuations in views of aging over months, days, and moments have been demonstrated, and theoretical suggestions provide hypotheses, but we know little about the causes of such fluctuations. While most studies have been longitudinal (across years) and cross-sectional, there is a gap in the literature that addresses these shorter timelines, especially within-day variations. Furthermore, the effects of views of aging on developmental outcomes are well documented, we have limited knowledge about what influences views of aging. This is a result of fewer studies on this directionality, and the fact that those who have tried, have struggled to reveal such couplings.

This thesis contains three distinct and cumulative studies, addressing several of the previously identified gaps in knowledge. It has therefore been composed with the following overarching aims: 1) identify the significance of utilizing different short-term timeframes when studying views of aging dynamics 2) investigate factors that are associated with changes in views of aging at such time frames with a focus on health, cognition and emotions, 3) to see how different (internal) aging-relevant contexts can moderate the influence of these factors. I also aimed to examine how various information pathways affect subjective aging: Chapter 2 explores the psychological pathway with cognition and emotion related to the COVID-19 pandemic, Chapter 3 explores the behavioral pathway with physical activity, and Chapter 4 explores physical pathways with physical health problems.

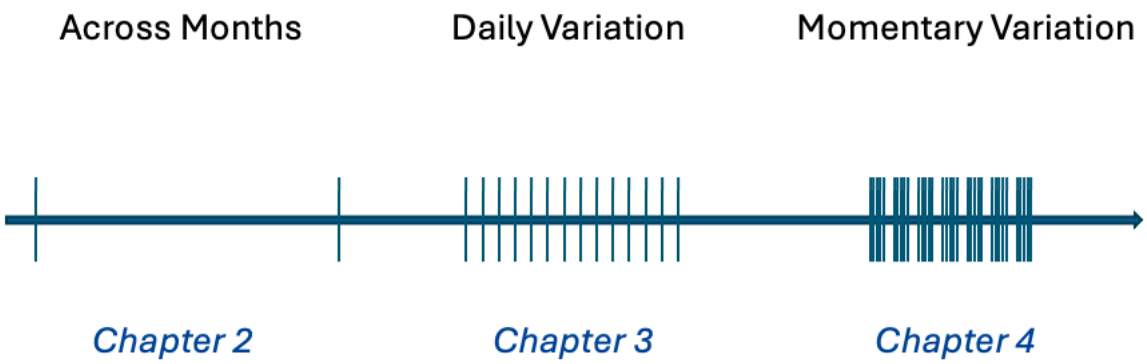

Figure 3. Visualization of the timeframes of each study. Vertical lines represent measurement occasions. The horizontal line represents time.

Publications

Chapter 2 – Subjective Age, Worry, and Risk-Related Perceptions in Older Adults in Times of a Pandemic

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The subsequent article has been published as follows:

Tingvold, M., Albert, I., Hoffmann, M., Murdock, E., Nell, J., & Kornadt, A. E. (2022). Subjective age, worry and risk-related perceptions in older adults in times of a pandemic. *Plos one*, *17*(9), e0274293.

The online supplemental material is included in the appendix.

2.1 Abstract

During the Covid-19 pandemic, older people have been in the spotlight of the public debate. Given their higher risk of severe outcomes of the disease, they have been described as especially vulnerable and as a burden to others and society. We thus wanted to investigate how older people's perception of their own age, that is their subjective age, as well as their Covid-19 related risks and worries were related during the pandemic and whether these relationships varied according to participants' subjective health. We used data from the longitudinal CRISIS study which was conducted in the Grand-Duchy of Luxembourg in June and October 2020. Participants were aged 60-98 and responded on questionnaires regarding their subjective age, worry of falling ill with Covid-19, perceived risk of contracting the virus, perceived risk of falling seriously ill if they contracted Covid-19, as well as their subjective health and covariates. Three cross-lagged panel models were constructed to explore the longitudinal, bidirectional relationships between the variables. Cross-sectionally, a higher subjective age was related to more perceived risk of a serious course of disease. Longitudinally, subjective age and worry did not show any significant association over time, and neither did subjective age and perceived risk of contracting the virus. However, subjective health significantly moderated the relationship of worry and subjective age, showing different trajectories in the relationship depending on whether subjective health was good or bad. Higher perceived risk of falling seriously ill increased subjective age over time. Again, subjective health moderated this relationship: the perceived risk of falling seriously ill affected subjective age only for those with better subjective health. Our findings show the interactive relationship between subjective age and Covid-19 related cognitions and emotions and provide guidance for identifying older people that are most susceptible for negative age-related communication during the pandemic.

2.2 Introduction

The current pandemic spreading through our societies has put a spotlight on the older generations. The main reason for this increased attention is that on average the risk of becoming seriously ill or dying from Covid-19 increases with chronological age (Grasselli et al., 2020) and many public measures have been taken to shield older people from exposure to the virus. Due to the associated risk of a severe course of the disease and mortality that comes with higher age, older people have been portrayed as highly vulnerable and in need of protection and care (Cohn-Schwartz & Ayalon, 2020), sometimes irrespective of their own wishes. Related is also the narrative that older people are seen as a burden to society due to the high amount of medical resources they require in already stretched health care systems, in addition to the effort that other population groups need to invest in protecting this vulnerable group (Cohn-Schwartz & Ayalon, 2020). These narratives of vulnerability and burden neglect the fact that older people represent a highly heterogeneous group: increased risks neither apply directly to each older person as we observe large individual differences in health status in later life, nor are older people universally vulnerable but can contribute to societal efforts in combatting the Covid-19 crisis. Experts on aging have raised questions regarding secondary impacts on older people of both the public debate and the safety measures, such as an increase in ageism and the related effect on older people's wellbeing (Ayalon, 2020; Cohn-Schwartz & Ayalon, 2020; Ehni & Wahl, 2020; Meisner, 2020). Therefore, we need empirical evidence on how this discourse regarding aging affects older adults themselves and how their own experience of age as well as their own experience of risks and worries interact. Given the prominent focus on older people in the pandemic discourse, we aim to investigate the reciprocal relationship between the age people feel, i.e., their subjective age, their worries as well as their perception of their own risks regarding Covid-19 during this historical time.

Subjective Age and the Pandemic Discourse

Although chronological age has been closely linked to many health outcomes, it does not reflect the aging process in its entirety (MacDonald et al., 2011), as subjective experiences of aging are highly important for development (Diehl et al., 2015). Subjective age, for instance, refers to how old people feel in relation to their chronological age (Kotter-Gruhn et al., 2015). It reflects how people view their own aging process and is thus a part of their age identity (Debreczeni & Bailey, 2020). From a developmental perspective, subjective age shows a distinct lifespan trajectory: in earlier life people feel generally older than their actual age and as they grow older they feel increasingly younger (Kotter-Gruhn et al., 2015; Montepare, 2009). Subjective age can be an indicator of different aging processes as it has been termed a "biopsychosocial marker" of aging (Stephan et al., 2018). It has shown to be sensitive to both biological and psychosocial changes, such as stressor exposure and biological aging, which not only increase the age people feel on a daily basis but also over time (Bellingtier et al., 2017; Stephan et al., 2015).

In terms of predictive relevance for development, a lower subjective age is also associated with beneficial outcomes for middle-aged and older adults: feeling younger than one's chronological age, at least to a certain degree (Blöchl et al., 2021), is longitudinally related to physical health factors such as better physical health, health behaviour and self-rated health (Spuling et al., 2013; Stephan et al., 2013; Westerhof et al., 2014a). A meta-analysis by Debreczeni and Bailey (2020) found that a younger subjective age is associated with reduced depressive symptoms as well as increased subjective wellbeing and better cognitive performance. In addition, a recent study showed an effect of subjective age on the relations between psychological symptoms; people with an older subjective age had a stronger effect of anxiety sensitivity on anxiety and depression (Avidor et al., 2021). This influence of subjective age on outcome variables has also been corroborated by experimental studies. For instance, after receiving positive feedback from a hand-grip strength test, participants reported

a younger subjective age and increased their performance on a second test, compared to participants who received no feedback (Stephan et al., 2013). In sum, this shows that subjective age can serve as both predictor and outcome in relation to variables like health and stress and, that overall, a younger subjective age is linked to better health and wellbeing in later life.

In times of a pandemic, in which age plays a major role in terms of actual and perceived risk, risk communication, media discourse and policy decision making, subjective age remains highly relevant and important to study. On the one hand, subjective age can serve as a coping mechanism for older people, allowing to distance oneself from ones' actual age and the related risks and worries, especially when belonging to the group of older people has negative implications (Weiss & Kornadt, 2018). This distancing effect would mean that people who feel threatened by being placed into the risk group of "older people" could cope with this challenge by distancing themselves from this group (e.g., by social comparisons, or stressing their "younger" characteristics), which might ultimately result in a lower subjective age. Previous studies have indeed shown that subjective age had a protective function when facing aging-related stereotypes, protecting the individual from negative views and vulnerabilities (Kornadt et al., 2018; Wurm et al., 2017), or when feeling lonely due to the pandemic and psychiatric symptoms (Shrira et al., 2020). Another study showed that when Covid-19 infection rates went up peoples' subjective ages decreased (Wettstein & Wahl, 2022), suggesting a distancing effect when risk is especially high. Interestingly, the effect was stronger for older individuals and for people who reported stronger health concerns. Finally, older people with more positive self-perceptions of aging appeared more resilient during the pandemic outbreak, indicating that subjective experiences of own aging can play an important role in protecting the individual from negative outcomes caused by the pandemic (Losada-Baltar et al., 2020).

However, there is also reason to assume that exposure to the age-related issues in the current pandemic might lead to people feeling older. In daily diary studies, individuals reported older subjective ages on days with more stress- and negative affective experiences (Kotter-Grühn et al., 2015) and perceived stress seems to increase subjective age over longer periods of time (Wettstein et al., 2021). Such experiences may be more frequent in the pandemic situation. Earlier studies have also shown associations between prolonged stress exposure and traumatic experiences with accelerated subjective aging (Avidor et al., 2014). These findings give rise to the idea that subjective age might increase in the current pandemic situation. Furthermore, the pandemic discourse could also make age and one's belonging to a certain risk group more salient (see also (Kornadt et al., 2021)), thereby making older people face their own vulnerability, ultimately resulting in older subjective ages.

These competing hypotheses, the distancing- and the stress hypothesis, were first brought forward and tested in a study by Terracciano et al. (2020) who at the beginning of 2020 (January to April), investigated the trajectories of subjective age in a large US sample of persons aged 18 years or older. The authors also investigated predictors of change in subjective age and found that people felt younger over the course of this early stage in the pandemic. The change in subjective age was predicted by the belief that the Corona virus is especially threatening to older people. In other words, the results align with the distancing hypothesis as a stronger perception of threat was predicting a younger subjective age. However, this study did not follow-up on participants after the initial phase of the pandemic, and it did not explicitly link subjective age with personal assessments of risk and worry. In addition, the study included both younger and older adults and did not focus especially on those who are most likely affected by the negative pandemic discourse. Besides, the study did not investigate bidirectional relationships, acknowledging that a younger subjective age might also be a resource which might ameliorate fears and age-related threatening situations (Weiss

& Kornadt, 2018). Furthermore, ones' health status most likely plays a role for subjective age during the pandemic and the relation to risk (perceptions) and worries.

Subjective Age, Worry and Risk Perception

Given the increased risk of severe progression of disease and mortality from Covid-19 in higher chronological ages (Caramelo et al., 2020), which was also highly present in the pandemic discourse, we wanted to investigate the link of subjective age to worry about Covid and to the perceived risk of contracting the virus and the risks of becoming seriously ill.

In general, worry is described as a negative chain of cognitions that represents an attempt at mental problem solving of an issue, whose outcome is unknown and (thus) has the possibility of being negative (Williams, 2013). According to Kummeneje and Rundmo (2019) worry is stipulated by the anticipation of negative and uncertain outcomes, and in such, a state of emotions related to how one perceives the situation. Maxfield and Pituch (2020) found that worry about Covid-19 does indeed increase with chronological age and in a study by Inbar and Shinan-Altman (2021), a negative association between age and emotional reactions to the pandemic was found. This is in line with other findings indicating that high-risk populations show more severe psychological reactions to the pandemic (Inbar & Shinan-Altman, 2021). Subjective age might be a central factor in this relationship, since feeling older might manifest the perception of being part of the risk group and thereby, increase personal relevance and thus heightened worries. Indeed, a recent study by Greenblatt-Kimron et al. (2021) showed that Covid-19 related worries predicted peritraumatic stress, with an effect stronger for those who felt they were getting older faster. Another recent study by Ayalon and Cohn-Schwartz (2021) showed that self-perceptions of aging and perceived age-based discrimination in healthcare settings were significant predictors of health worries related to Covid-19.

Closely related to one's worries are the risk perceptions one has of a situation. People have in general been concerned about Covid-19 (Dryhurst et al., 2020; Lanciano et al., 2020), yet they underestimate their own risk. A study based on a US adult population showed that

people underestimate their absolute and relative fatality risk compared to epidemiological figures (Niepel et al., 2020). Given that higher age is indeed linked to an increased likelihood of falling seriously ill with Covid-19, how likely people think it could be that they would contract the virus and how sick they think they would become, should also depend on their perceived belonging to the risk group. In a study by Bruine de Bruin (2020), older chronological age was indeed associated with greater perceived risk of dying if getting ill with the Corona virus, but the perceived risk was considered lower for contracting the virus. Given that subjective age might be an even better indicator of one's perception of belonging to a risk group, our results could be in line with those of Bruine de Bruin (2020), where older subjective ages are related to greater risk of severe Covid-19 illness but less with the risk perception of contracting the virus.

The role of Bidirectional Relationships

Given the importance of subjective age as a predictor of wellbeing and health, factors affecting subjective age have also been of interest in previous studies. Psychological, social and biomedical factors like perceived age discrimination and reduced grip strength can explain variations in subjective age (Stephan et al., 2015). As noted above, the relationship between subjective age, worry and risk perceptions is open to three possibilities: a) subjective age as an antecedent of worry and risk perceptions, as feeling older might make people more susceptible for age-related negative cognitions and emotions; b) as subjective age can be a marker of developmental processes, and increased worry and risk perception might increase negative affect and be indicative of an older identity, worry and risk perceptions could be antecedents for subjective age, c) given that both processes can co-exist, a bidirectional relationship, in which subjective age predicts worry and risk perception and vice versa is also plausible.

Empirically, only a few studies have explored the bidirectionality of subjective age and its relation to other constructs so far. Spuling et al. (2013) investigated the relationship

between different subjective age dimensions and health status measures. A more recent study explored the bidirectional relationship between subjective age and depressive symptoms and activities of daily living (Rippon & Steptoe, 2018). Both studies concluded that subjective age was the antecedent of the other constructs. Wettstein and colleagues (Wettstein et al., 2021) on the other hand, found a bidirectional relationship in their study linking subjective age and perceived stress. Thus, more studies are needed in order to fully understand the bidirectional relationships of subjective age and other variables.

The Moderating Role of Health Status

Compromised physical health is a major factor for severe outcomes of a Covid-19 infection (Albitar et al., 2020; Zhang et al., 2020), and underlying health conditions are also partially responsible for the higher risk of older adults for severe courses of the disease (Shahid et al., 2020). Therefore, health needs to be considered when investigating worry and risk perceptions regarding Covid-19, especially in older people. An indicator for health processes is perceived, self-rated or subjective health, which has high predictive value for mortality (Idler & Benyamini, 1997), and has also been linked to subjective age (Benyamini & Burns, 2020). In the pandemic context, Inbar and Shinan-Altman (2021) found that emotional reactions to the pandemic were higher for those who rated their health status as lower. In line with these results there is reason to believe that ones' health status could also moderate the relationship of worry and subjective age: Those with higher subjective age and worse health status might feel especially worried and at risk, because they combine two risk factors (belonging to an older age group and worse health status) and those who perceive their health status as worse might have more problems distancing themselves from the risk group when perceiving threat, since worse perceived health might be a factor that is associated with belonging to an older age group.

Aim and Hypotheses

Given the importance of age in the actual risk and the risk communication to the public during the Covid-19-pandemic, as well as the importance of subjective age for health and well-being in later life, the current study sets out to investigate the associations between worry, perceived risks, health status and subjective age among older people during the first year of the pandemic (Albitar et al., 2020; Bruine de Bruin, 2020; Maxfield & Pituch, 2020). To the best of our knowledge, previous studies have not linked subjective age directly to risk perceptions and worries over time in a bidirectional way and have not addressed the moderating role of one's health status.

Our first hypothesis is that worry and perceived risks (contracting the virus, falling seriously ill) will affect how old people feel. In line with the findings by Terracciano et al. (2020) as well as Wahl & Wettstein (Wettstein & Wahl, 2022), we assume that older people will distance themselves from their actual age over time in the context of the Covid-19 pandemic, if they have more Covid-related worry and a higher risk perception: Those who feel more worried or perceive higher risk of infection or falling seriously ill at first measurement, will feel younger three months later, to psychologically remove themselves from the risk group (cf. (Kornadt et al., 2018; Weiss & Kornadt, 2018).

Our second hypothesis is targeting how subjective age affects how worried older people are and how much risk they perceive. Given that people might base their worries and risk perceptions on the age they feel like, and that distancing from the older age group might be a protective mechanism, we expected that people who feel older at the first measurement point should worry more three months later and perceive more risk of infection and of falling seriously ill.

Thirdly, we expect subjective health to moderate the relationships. Given that a lower health status might hamper distancing from the at-risk group, we expect that the distancing effect (i.e., feeling younger) due to heightened worry and risk perception will only emerge if

people are in good health. For the other direction, we assume that those who feel younger will feel even less worried and at risk if they perceive themselves to be in good health. Here we also expect a particularly strong moderation effect for the relationship between subjective age and perceived risk of falling seriously ill, as the latter should be more closely related to ones' health status.

2.3 Methods

Sample and Procedure

We use data from the CRISIS study which was conducted in the Grand-Duchy of Luxembourg in June and October 2020, which represented a time between the first and second pandemic wave, when some relaxations of sanitary measures had already been in place. At the first wave a total of $N = 611$ community-dwelling, older participants from Luxemburg were recruited by a survey research institute (TNS ILRES). Participants were aged 60-98 (Mean = 69.92, SD = 6.97), and 49.6% were female. The survey was conducted partly by phone through random digit dialling ($n = 240$, response rate 27%), and partly online, recruiting people from a database of Luxembourgish residents who had agreed to be contacted for online surveys ($n = 371$, response rate 40%). The participants responded to questions on socio-demographic information, their concerns about the Covid-19 crisis in Luxembourg in general, their personal situation during the crisis, subjective age, worries and a variety of other risk and resilience factors. Informed consent was given verbally for those who participated by phone, and in written format for those participating online. The study was approved by the Ethics Review Panel of the University of Luxemburg (ERP 20-042-C CRISIS). Participants were invited for a second wave in October, in which $N = 523$ persons participated. For more details on the sample, procedure, and assessment, see Kornadt et al. (Kornadt et al., 2021).

Measures

Subjective Age

Subjective age (SA) was assessed at both timepoints (SA T1 and SA T2, respectively) by asking people "Aside from your actual age: how old do you feel in years?". Participants' chronological ages were then subtracted from participants' felt age, so that negative values indicate feeling younger. Following recommended practice, outliers, i.e., values that were three standard deviations above or below the mean were removed (T1: more than 38 years younger or more that 18 years older, 1.3% of cases; T2: more than 37 years younger or more than 19 years older, 0.8% of cases).

Subjective Health

Subjective health (SH) was measured at the first timepoint by asking, "How would you rate your current state of health?", and participants indicated their subjective health on a five-point scale ranging from "very good" to "very bad".

Worry About Falling ill with Covid-19

Worry was measured at both timepoints (WORRY T1 and WORRY T2) by asking participants to indicate how much they agreed with the statement "I am worried about falling ill with Covid-19", giving their response on a four-point scale ranging from "totally agree" to "absolutely not agree".

Perceived Risk

Perceived risk at both timepoints was assessed by two questions, related to the risk of falling ill (PRISK T1 and PRISK T2), and to the risk of developing a serious course of disease (PRISK-S T1 and PRISK-S T2). The former was measured by asking participants "To which extent do you estimate the risk of yourself falling ill with Covid-19?" and to indicate their responses on a five-point scale ranging from "very likely" to "very unlikely". PRISK-S was assessed with the question "If you would fall ill with Covid-19, how likely do you think it is that you would develop a serious course of disease?". Participants again gave their responses

on a five-point scale ranging from “very likely” to “very unlikely”. For both sets of questions, participants could indicate whether they had already contracted the virus and those who answered in the affirmative (T1: $N = 8$, T2*:* $N = 5$) were excluded from further analyses.

Finally, participants also reported their chronological age, gender (1 = male, 2 = female), and level of education (higher values represents higher qualifications).

Analyses

Descriptive statistics and bivariate correlations were computed with SPSS 26 to address means and bivariate relationships between variables. All variables were recoded so that higher values indicate higher endorsement. To examine the longitudinal, bidirectional relationships between subjective age, worry and risk perceptions we computed separate cross-lagged panel models for each variable (Fig 1) using Mplus 8 (Muthén, 1998-2017). We first estimated the model including only subjective age and the respective worry/risk variables. In a second step, chronological age, education, and gender were added as covariates. We allowed correlations of the covariates with the T1 predictors and used the covariates as predictors of the T2 outcome variables (Fig 2.1). In a third step, subjective health was introduced as a moderator for the longitudinal paths. Before computing interaction terms, all variables were standardized.

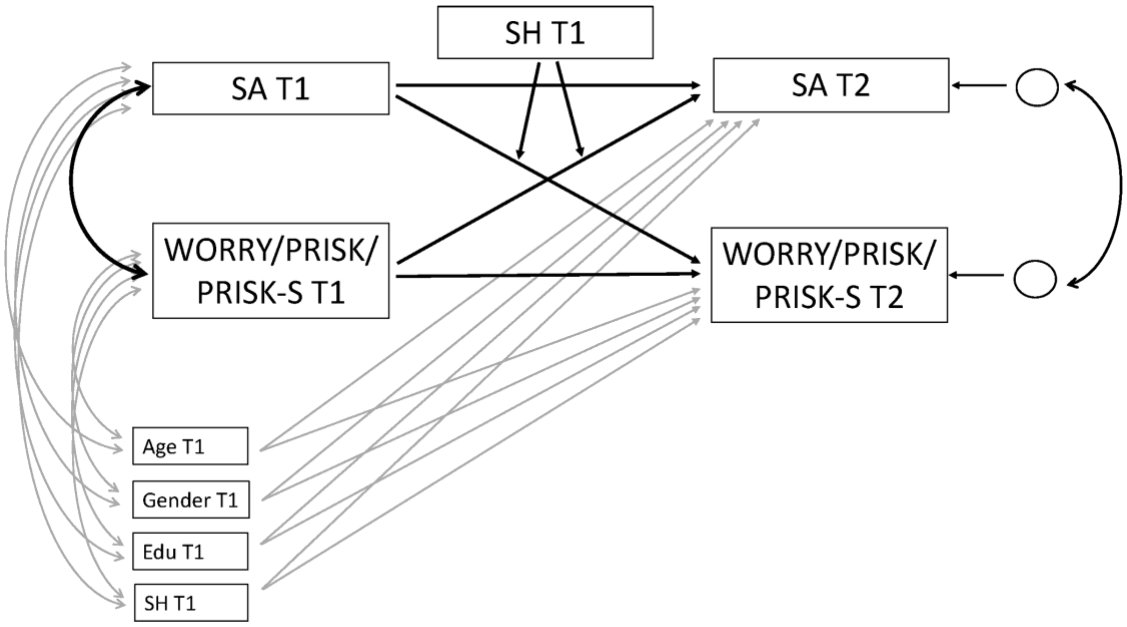

Fig 2.1. Cross-lagged panel model showing the bidirectional, longitudinal relationship between subjective age (SA) and the three variables worry (WRY), risk of falling ill (PRISK), and risk of serious course of disease (PRISKS), including all covariates (bivariate correlations between covariates are not displayed for reasons of parsimony). Please note that separate models were run for all three variables. T1 = timepoint 1; T2 = timepoint 2; Edu = Education.

2.4 Results

Descriptive Statistics and Bivariate Correlations

Descriptive statistics and bivariate correlations for all variables are presented in Table 1. On average, people felt younger than their chronological age. Mean values of subjective age increased over time (t (448) = -4.302, p < .001), indicating that on average, people felt somewhat older at the second compared to the first timepoint. Subjective age was significantly and positively related to perceived risk of serious disease at both timepoints indicating that people who felt older also perceived higher risk of serious disease. There was also a significant and negative relation between subjective age and subjective health, those

who felt older also perceived their health to be worse. However, there was no significant correlation between subjective age and worry. Worry at timepoint 1 had a small but significant negative correlation with perceived risk of getting infected at timepoint 1, indicating that those who worried more perceived their risk as lower. Subjective health was negatively correlated with risk of serious disease at both timepoints, but only to risk of contracting the virus at timepoint 1, implying that those experiencing worse health perceived their risks as higher.

Table 1

Descriptive statistics and bivariate correlations at both time points.

Variable	*N*	*M*	SD	1	2	3	4	5	6	7	8	9	10	11
1. SA T1	532	-10.03	7.59	-										
2. Worry T1	601	2.396	0.84	0.02	-									
3. PRisk T1	566	2.224	0.80	-0.01	-.11*	-								
4. Prisk-S T1	540	-2.224	0.88	0.13*	-0.02	0.23*	-							
5. SH	609	1.98	0.72	-0.26*	0.01	-0.07*	-0.37*	-						
6. SA T2	503	-8.532	7.26	0.60*	-0.02	0.02	0.19*	-0.21*	-					
7. Worry T2	513	2.452	0.83	0.00	0.05	-0.09*	-0.08	0.06	0.05	-				
8. PRisk T2	489	2.269	0.80	0.00	0.00	0.46*	0.27*	-0.01	0.12*	-0.01	-			
9. Prisk-S T2	458	2.633	0.88	0.12*	0.11	0.17*	0.57*	-0.30*	0.17*	0.04	0.25*	-		
10. Age	608	69.92	6.97	-0.10*	0.04	-0.05	0.15*	-0.13*	-0.07	-0.05	-0.02	0.12*	-	
11. Edu	544	3.38	1.15	0.05	-0.01	-0.02	-0.07*	0.17*	0.10*	0.06	0.03	-0.09	-0.13*	-
12. Gender	611			0.01	-0.05	0.05	-0.05	0.01	-0.06	-0.03	-0.01	-0.04	-0.06	-0.16*

T1, Timepoint1; T2, Timepoint 2; Gender 1. Male ; 2, Female; SA, Subjective Age; Prisk, Perceived Risk of contracting virus; Prisk-S, Perceived Risk of Serious disease course; EDU, education.

** P = < .0.05.*

Longitudinal Relation of Subjective Age and Worry

Model fit indices for all cross-lagged models are presented in Table 2. The first model with worry and subjective age showed a significant positive result for the longitudinal path from subjective age to worry (Table 3, Model 1), indicating that those with higher subjective age at T1 worried more at the second time point, but this significant effect disappeared when the covariates were entered into the model (Table 3, Model 2). The covariates age, education, and gender themselves did not significantly predict any of the dependent variables (Appendix Chapter 2, Table A2.1). When including subjective health as a moderator, subjective health positively moderated the longitudinal path from worry to subjective age (Table 3, Model 3),

even in the presence of the covariates. Simple slope analyses showed that the path from worry to subjective age was significant for high and low health status (+/- SD above and below the mean, respectively), but differed in direction (Fig 2.2). For those with worse health status, a lower amount of worry at T1 predicted an older subjective age at T2 (b = 1.061, p = *.008)*. For those with a better health status, more worry at T1 predicted an older subjective age at T2 (b = -0.795, p = *.031)*. As shown in Fig 2, the difference between groups of high and low health groups was largest at lower levels of worry, while the effect was similar at high levels of worry. There was no significant correlation between the residuals of worry and subjective age at T2 in any of the models including worry and subjective age (simple model: r_c = .05, p = .278), indicating that no correlated changes could be observed beyond the changes explained by the model.

Table 2

Model fit indices for the cross-lagged regression models

	X2 (df)	*p*	RMSEA (90%CII)	CFI	SRMR
Model 1: Simple model SA and Worry	369.668 (5)	0.00	0[0.00,0.00]	1.00	0.00
Model 1: Simple model SA and Worry, with covariates	386.424 (13)	0.00	0[0.00,0.00]	1.00	0.00
Model 1: Model with SH as moderator, with covariates	403.373 (17)	0.00	0.06 [0.01,0.11]	0.99	0.01
Model 2: Simple model SA and PRISK	326.046 (5)	0.00	0[0.00,0.00]	0.01	0.00
Model 2: Simple model SA and PRISK, with covariates	342.116 (13)	0.00	0[0.00,0.00]	0.01	0.00
Model 2: Model with SH as Moderator, with covariates	353.411 (17)	0.00	.075 [0.03,0.13]	0.98	0.16
Model 3: Simple model SA and PRISK-S	389.144 (5)	0.00	0 [0.00,0.00]	0.01	0.00
Model 3: Simple model SA and PRISK-S, with covariates	413.897 (13)	0.00	0 [0.00,0.00]	0.01	0.00
Model 3: Model with SH as moderator, with covariates	428.190 (17)	0.00	0.05 [0.00,0.01]	0.99	0.01

Model 1, subjective age and worry; Model 2, subjective age and perceived risk of infection; Model 3, subjective age and perceived risk of serious disease. RMSEA, root-mean-square-error of approximation; CFI, comparative fit index; SRMR, standardized root mean square residual. SA, Subjective Age; Prisk, Perceived Risk of contracting virus; Prisk-S, Perceived Risk of Serious course of disease.

Table 3

Standardized estimates for the cross-lagged regression models including subjective age and worry of falling ill with Covid-19

	Initial Correlation	Stability	Crossed-lagged effect		Moderator effect		Direct effect		Residual Correlation
CL Model with SA and Worry	**rWorry1↔SA1**	**SA1↔SA2**	**Worry1→Worry2**	**Worry1→SA2**	**SA1→Worry2**	**Worry1→SA2**	**SA1→Worry2**	**SH→Worry2**	**SH→SA2**	**Worry2↔SA2**
1 Simple Model	.102*	.623*	.518*	0.021	.079*					.050
2 Simple Model with Covariates	.103*	.605*	.511*	0.009	0.058					.039
3 Model with Subjective Health	.111	.618*	.512*	0.018	0.071	0.137*	0.034	-0.058	-0.086*	.030

Models with covariates include age, gender, education and subjective health at timepoint 1. Worry1, worry of falling ill with Covid-19 at timepoint 1; SA1, subjective age at timepoint 1; Worry2, worry of falling ill with Covid-19 at timepoint 2; SA2, subjective age at timepoint 2; SH, subjective health.

**p<0.05*

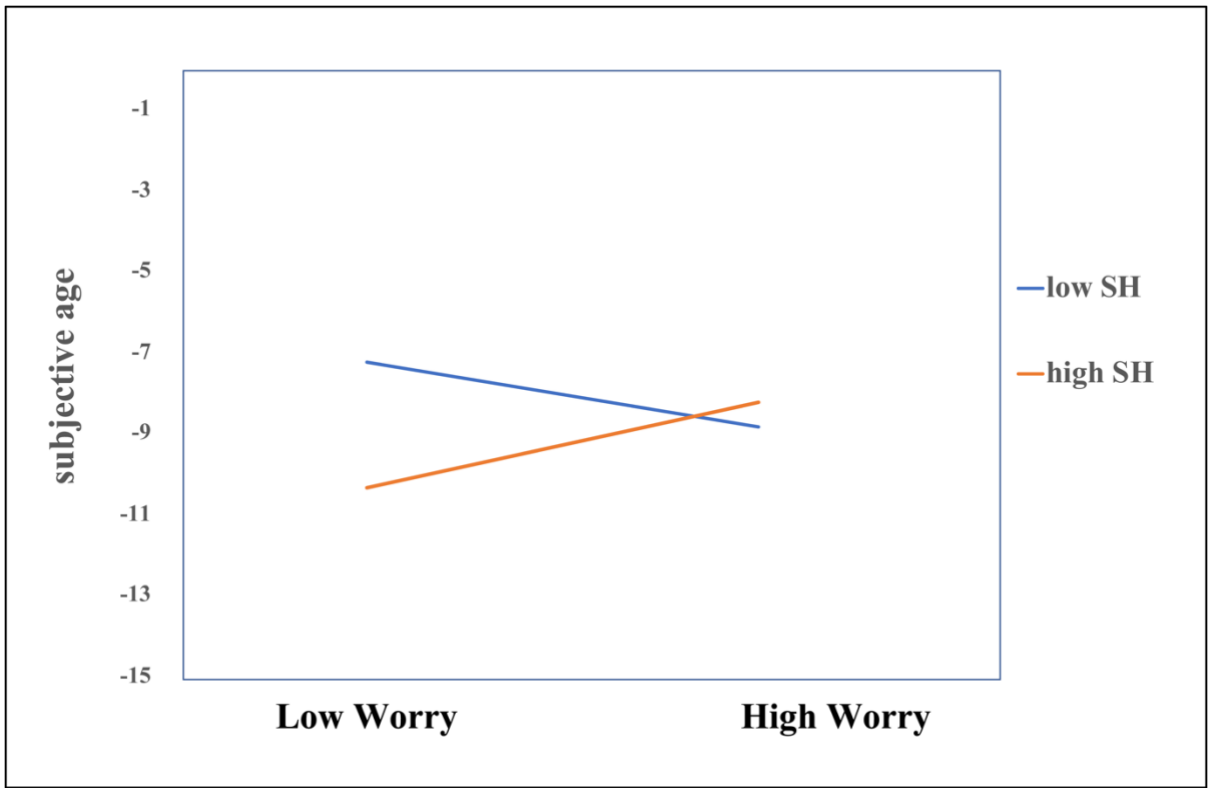

Fig 2.2. Simple slopes for the effect of worry at T1 predicting subjective age at T2, moderated by subjective health (SH). High and low worry and subjective health groups represent values 1 SD above and below the mean, respectively. Analyses are controlled for age, gender, education, and subjective health.

Subjective Age and Perceived Risk of Covid-19 Infection

None of the cross-lagged models which contained subjective age and perceived risk of a Covid-19 infection yielded any significant longitudinal relationship, and there was also no moderation effect of subjective health (Table 4). The covariates age, education, and gender did not significantly predict any of the dependent variables in any of the models, including subjective age and perceived risk of infection (see Appendix, A2.2). There was a significant correlation between the residuals of the T2 variables in all models including subjective age and perceived risk of infection (model 1: $r_c = .15$, $p = .001$), including the final model (Table

3, model 3), representing correlated changes irrespective of directional relationships: as subjective age increased, so did perceived risk of infection.

Table 4

Standardized estimates for the cross-lagged regression models including subjective age and perceived risk of infection

	Initial Correlation	Stability		Crossed-lagged effect		Moderator effect		Direct effect		Residual Correlation
CL Model, SA and Prisk	**rPrisk1↔SA1**	**SA1↔SA2**	**Prisk1→Prisk2**	**Prisk1→SA2**	**SA1→Prisk2**	**Prisk1→SA2**	**SA1→Prisk2**	**SH→Prisk2**	**SH→SA2**	**Prisk2↔SA2**
1 Simple Model	-0.016	.624*	.489*	0.009	-0.013					.154*
2 Simple Model with Covariates	-0.013	.605*	.489*	0.002	-0.005					.158*
3 Model with Subjective Health	-0.012	.604*	.489*	-0.005	0	0.062	0.021	0.013	-0.079	.154*

Models with covariates include age, gender, education and subjective health at timepoint 1. Prisk1, perceived risk of contracting the Corona virus at timepoint 1; SA1, subjective age at timepoint 1; Prisk2, perceived risk of contracting the Corona virus at timepoint 2; SA2, subjective age at timepoint 2; SH, subjective health.

**p<0.05*

Subjective Age and Perceived Risk of Falling Seriously ill With Covid-19

The cross-lagged models for subjective age and perceived risk of serious illness with Covid-19 yielded a significant positive relationship from perceived risk at T1 to subjective age at T2 indicating that those who perceive their risk as higher feel older over time (Table 5, Model 1), and this effect also persisted when entering the covariates (Table 5, Model 2). The covariates age, education, and gender did not significantly predict any of the dependent variables in the models including subjective age and perceived risk of falling seriously ill (see S4 Appendix, Table 3). Better subjective health at T1 predicted lower perceived risk of serious illness at T2 (β = -.114, p = .010). Subjective health was also a significant moderator of the relationship between perceived risk of falling seriously ill and subjective age (Table 5, Model 3). Simple slopes analyses indicated that risk of falling seriously ill predicted subjective age only for those with better subjective health (b = 1.567, p = <.001), whereas there was no effect of risk for those with low subjective health (b = -0.248, p = .555) (Fig 2.3). Participants with a good subjective health felt younger if they perceived their risk of falling seriously ill as low, and older if they perceived their risk as high. There was a significant correlation between the residuals of the T2 variables in all models including subjective age and perceived risk of falling seriously ill (model 1: r_c = .107, p = .030), indicating that as subjective age increased, so did perceived risk of falling seriously ill, irrespective of bidirectional relationships.

Table 5

Standardized estimates for the cross-lagged regression models including subjective age, and perceived risk of falling seriously ill with Covid-19

	Initial Correlation	Stability		Crossed-lagged effect		Moderator effect		Direct effect		Residual Correlation
CL Model, SA and PriskS	**rPriskS↔SA1**	**SA1↔ SA2**	**PriskS1→PriskS2**	**PriskS1→SA2**	**SA1→PriskS2**	**PriskS1→SA2**	**SA1→Prisk2**	**SH→PriskS2**	**SH→SA2**	**PriskS2↔SA2**
1 Simple Model	0.148*	.610*	.584*	.104*	0.029					.104*
2 Simple Model with Covariates	0.146*	.599*	.533*	.091*	0.019					.105*
3 Model with Subjective Health	0.147*	611*	.533*	.091*	0.021	.136*	0.005	-.114*	-0.067	.107*

Models with covariates include age, gender, education and subjective health at timepoint 1. Prisk-S1, perceived risk of serious disease course at timepoint 1; SA1 subjective age at timepoint 1; Prisk-S2, perceived risk of serious disease course at timepoint 2; SA2, subjective age at timepoint 2; SH, subjective health.

**p<0.05*

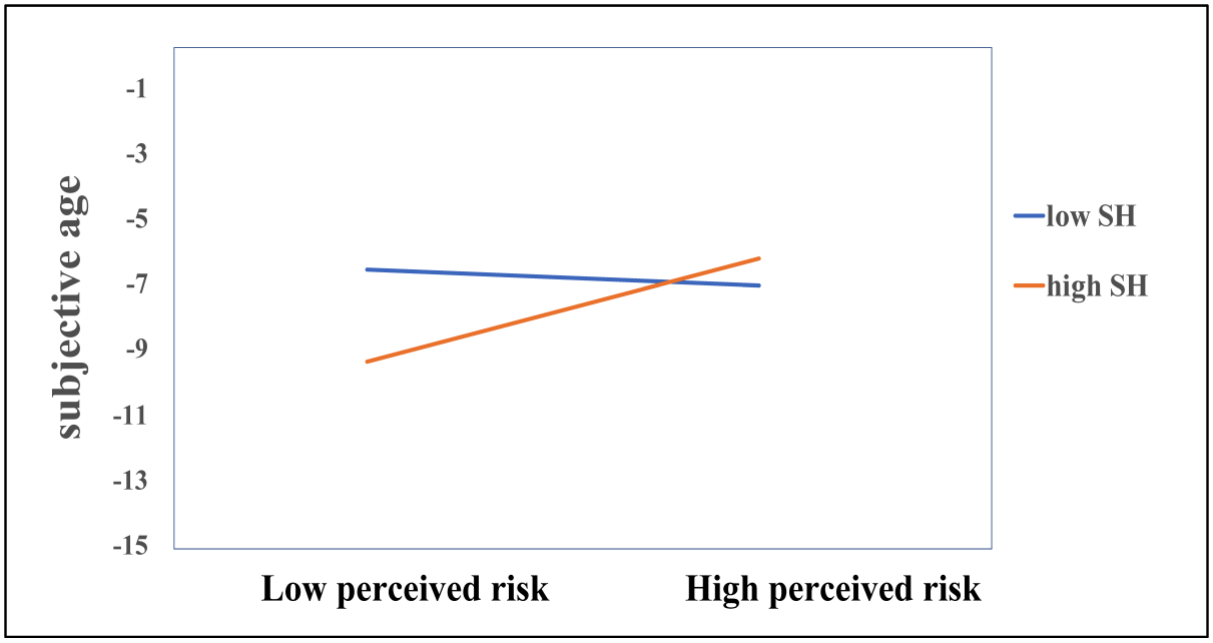

Figure 2.3. Simple slopes for the effect of perceived risk of serious disease course at T1 predicting subjective age at T2, moderated by subjective health (SH). High and low perceived risk of falling seriously ill and subjective health groups represent values 1 SD above and below the mean, respectively. Analyses are controlled for age, gender, education, and subjective health.

2.5 Discussion

Given the high relevance of belonging to the risk group of older persons during the Covid-19 pandemic, our study aimed at investigating the bidirectional relationship between how old people feel and their worries and perceptions of risk concerning the virus while also including perceived health status as a moderator. We found that overall, subjective age increased over the course of the surveyed stage of the pandemic, indicating that on average, participants felt older in October 2020 compared to June 2020. A higher subjective age at T1 was cross-sectionally related to a higher perceived risk of serious course of disease, but not to worry or risk of infection. As for longitudinal relationships and contrary to our expectations,

neither worry nor perceived risk of contracting Covid-19 showed a significant independent relationship with subjective age in either direction. The relationship of worry and subjective age was dependent on subjective health, with an effect in opposite directions depending on whether subjective health was good or bad. For participants with poor subjective health at T1, the relation was negative meaning that those who worried more at T1 felt younger at T2 compared to those who worried less. For those with better subjective health the relation was positive indicating that if people worried more at T1 they felt older at T2 compared to those who worried less. As expected, perceived risk of falling seriously ill was a significant predictor for subjective age three months later, and health status moderated this relationship: amongst participants with a better subjective health, those who perceived their risk of serious disease as lower in June 2020 felt younger in October 2020, whereas for those with a poor subjective health their perceived risk of falling seriously ill had no effect on subjective age. Finally, we found significant residual correlations in both models including perceived risk, indicating correlates changes in the sense that increases in subjective age are associated with higher level of perceived risk of contracting the virus and of falling seriously ill, irrespective of directional relations.

The Effect of Worry and Risk Perceptions on Subjective Age and the Moderating Role of Subjective Health

Our results revealed that both worry of falling ill and perceived risk of falling seriously ill predicted subjective age three months later. However, the main effect was only significant for perceived risk of falling seriously ill. Regarding worry, we expected our results to be in line with the distancing hypothesis stating that people who experienced more worry and risk would feel younger over time to distance themselves from the risk group. On the contrary and in contrast to the results of Terracciano et al. (2020), we found that subjective age increased between measurement occasions as the pandemic progressed, and

that overall, worry did not predict subjective age over time. Only for participants with lower perceived health did more worry predict a younger subjective age. For participants with better subjective health, no distancing effect was found, but rather the contrary: more worry increased subjective age for those with good subjective health. Although those with worse health and more worry felt younger compared to those with a poorer health and less worry, there was not a big difference in the subjective ages between good and poor health for those with more worry. Thus, the protective effect of good subjective health on subjective age seems to be leveraged when people worry a lot. It might be interesting to consider this in terms of the effects of risk communication: Those older people who are in good health might have the most to lose and thus be especially susceptible to fear-inducing communication in terms of placing them in the risk group, thus their subjective age increases. Future studies should address this possibility and link it to objective risks of infection, such as number of Covid cases, which also seem to be relevant with regard to subjective age (Wettstein & Wahl, 2022).

Higher perceived risk of a serious course of disease did also not lead to distancing tendencies as the original models showed that more perceived risk of a serious course of disease predicted a higher subjective age. The effect became non-significant for participants who experienced their health as worse. Those with a better subjective health felt youngest when they perceived their risk as low, also in contrast to any distancing mechanism. In sum, neither the model with worry, nor the model with perceived risk of a serious course of disease gave clear support for the distancing hypothesis.

One factor that might have played a role regarding the differences of our effects compared to Terracciano and colleagues (Terracciano et al., 2020), is that our sample consisted mainly of older people (aged 60+), while their sample was aged 18 and older. People over the age of 60 were mainly lumped into one category of at-risk persons during the

pandemic, which might have contributed to the fact that chronological age did not play a major role in our results, compared to the age people felt like. Given these differences, it might be worthwhile to investigate the relations between subjective age and worries as well as risk perception in different stages of the lifespan and also at different points in time during the pandemic. Depending on the stage of the pandemic and the current focus of the discourse, the age-dependency of the relations might be highly dynamic.

Despite the lack of directional effects, we found significant positive residual correlations in models including both risk perceptions, which speaks for correlated changes between the variables beyond any directional relations. Other variables, such as sense of control, might thus be needed to be addressed to understand the relationship between perceived risk and subjective age. For instance, a study by Sesker and colleagues (Sesker et al., 2022), found that perceived control declined significantly during the early onset of the pandemic. As a lower sense of control can make older adults feel older on a daily basis (Bellingtier & Neupert, 2019), and we know that it is related to both subjective age and risk perceptions (Bellingtier & Neupert, 2019; Lanciano et al., 2020) incorporating sense of control into future analysis, we could gain a better understanding of the mechanisms behind subjective age.

Naturally, perceived health should be highly relevant for people's worries and risk perception during an ongoing health crisis, especially for older people. Our findings support this as health moderated the relationship of subjective age, worry, and risk perception. Relatedly, Ayalon and Cohn-Schwartz (2021) found that people with chronic illnesses tend to worry more about Covid-19, confirming the strong connection between health/illness and worries related to the pandemic. Furthermore, our findings suggest that the associations between subjective age, risk perception and worry are contingent on specific contextual factors, such as subjective health. In our view, the results indicate that the trajectories of

subjective age during the pandemic show big interindividual differences and depend on specific compositions of resources and stress factors. These resources and constrains could also be related to different domains. Interestingly, Lanciano and colleagues (Lanciano et al., 2020) found that perceived risk in the health domain was rather low compared to other risk perceptions, e.g., in the domain of work or institutional economy during the Covid-19 emergency. In future research it will be interesting to better understand which domains and what factors contribute to younger subjective ages and the way in which subjective age, risk perception and health interact over longer periods of time.

The Effect of Subjective Age on Worry and Risk Perception

In terms of bidirectional effects, we had hypothesized that subjective age would have an effect on worry and risk perceptions, and that his effect would follow the same trajectories as chronological age in the sense that people who felt younger would worry less and perceive their risk of getting infected with Covid-19 as lower (Bruine de Bruin, 2020; Inbar & Shinan-Altman, 2021). However, we did not find that subjective age predicted worry or perceived risks over the course of three months. Our first model including subjective age and worry yielded a small significant effect from subjective age to worry, but this effect did not hold when covariates were added. Overall, the results indicate that ones' subjective age may not be considered when worrying or estimating ones' risks of falling ill with Covid-19. However, as our study time was quite limited (3 months), we were not able to map dynamic relations between variables. There might be phases during the pandemic, when subjective age might be more predictive for people's worries and risk perceptions, that our design precluded to detect. Given that we found significant correlations at T1 between for instance, subjective age and perceived risk of falling seriously ill, there might have been some adaptations that had already taken place at earlier timepoints. In addition, subjective age may vary and be more potent depending on specific situations. As people most likely answered our questions while

staying at home, this might have represented a situation of security and control, which tend to lower subjective age (Bellingtier & Neupert, 2019), and as such people's perceptions of risk may be less affected.

Overall, factors other than subjective age might be more predictive of worries and risk perceptions, especially for older adults. We should thus consider for instance people's more general emotional states and anxiety levels, which we could not control for in the current study. Besides, older adults are found to show more emotional resilience than younger people and this seems to have persisted during the current pandemic (Carstensen et al., 2020). In sum, we should investigate whether there is a shift in which variables best predict worries and risk perceptions depending on the different stages of life after 60, and whether age differences in general tendencies of negative affect and anxiety might play a role in this regard.

Limitations and Directions for Future Research

Our study adds to previous studies of subjective age during the pandemic by exploring a bidirectional model including subjective age, worries- and perceptions of risk related to Covid-19, and by including health status as a moderator. We have contributed to nuancing the idea of subjective age as a coping mechanism specifically and to the complex nature of how people react to the ongoing pandemic more generally. Finally, our longitudinal data collection with a large sample of older adults was conducted at the beginning of the pandemic outbreak and has in such captured some of the early onset of reactions of older people related to the pandemic.

Some limitations still need to be pointed out which at the same time open directions for future research. As already mentioned, although we use longitudinal data, our data collection is limited to two time points between the first two waves of the covid outbreak in Luxembourg. Given the highly volatile nature of the pandemic, and the development of

vaccines that were first offered to older and at-risk individuals, it would have been interesting to see how the relationship between subjective age, worry, and risk perception develops over longer periods of time. Furthermore, our first data collection took place at the end of the first wave, when some adaptations and adjustments might already have taken place. Evidence for the time dependency of effects during the pandemic come from several studies. For instance, Li et al. (2021) found that in a US sample risk perceptions did impact preventive behaviour at the start of the pandemic, but over the course of the pandemic, preventive behaviour increased people's perception of infection-risk which again contributed to an increase in preventive behaviour. In addition, Niepel et al. (2020) found that respondents underestimated their fatality risk related to Covid-19 compared to epidemiological figures. However, the estimation became more accurate over time. These findings indicate that the relationships between worry, risk perceptions and other variables can change in strength and direction depending on specific conditions at a given time. Thus, future studies should aim at analysing dynamic, time-lagged, and bidirectional effects across all the waves of the pandemic, numbers of infection (Wettstein & Wahl, 2022) and the ongoing governmental restrictions and media images of older people. There is the possibility that the effects of worries, subjective age and health changes or increases over time as the pandemic situation develops, and feedback loops between variables might be possible.

In addition, our study is limited to the situation in Luxembourg. Subjective age has been found to have a stronger effect on health and survival in countries providing less welfare (Spuling et al., 2013). As our study is conducted in a state providing a high level of welfare than for example, the US, comparing our results to similar studies based on data from disparate countries could provide a better insight into the effect of culture- and environmental factors.

Furthermore, all constructs relevant in the current study were assessed using single items, which might limit the reliability of our results. Subjective age and subjective health are commonly assessed with single items, and those have proven to be quite powerful predictors of e.g., mortality and physical functioning (Benyamini & Burns, 2019; Westerhof et al., 2014b). However, even though subjective health is a relevant indicator in concertation with perceived risk, worry and subjective age, additional objective health information might have strengthened our results, but was not at our disposal. Besides, subjective age is a multidimensional construct (Kornadt et al., 2018), and thus, future studies should address in how far different dimensions of subjective age, such as ideal age and look age might show differential trajectories and relations.

Finally, in terms of our sample, our study included only participants who were willing and able to answer questions online or via phone. Thus, generalizations to the general or other populations should be considered cautiously.

2.6 Conclusion

Regardless of these limitations, our study is adding to the growing field of research investigating subjective age during the ongoing pandemic. We have shed light on the relationships between subjective age, worry and perceived risks and the role of people's perceived health. Our study reconfirms that subjective age is a complex construct that can play several roles in the developmental trajectory of aging. Rather rationally, older people are more concerned about having a serious course of disease if sick with Covid-19, than they are about contracting the virus. One's health status plays a crucial role in how subjective age relates to one's emotional and cognitive reactions to the pandemic as it can change the direction of effects.

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Chapter 3 – Daily Health Problems, Views of Aging, and the Moderating Role of Awareness of Age-Related Changes

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The subsequent article was submitted in February 2025 to the Journals of Gerontology, *Series B,* as a brief report.

3.1 Abstract

Objectives. Indicators of views of aging, such as people's subjective age or their perception of accelerated aging, are related to health problems: In both longitudinal and daily assessments, experiencing more health issues is associated with more negative subjective aging. In the current study, we were interested in awareness of age-related changes as a moderator of this relationship. We assumed that on days when participants experienced higher awareness of age-related gains, the coupling of daily health problems and subjective aging should be weaker, whereas it should be amplified on days when participants experienced higher awareness of age-related losses.

Methods. A sample of $N = 69$ participants aged 52 – 75 years ($M_{age} = 62.72$, $SD = 5.57$) reported their subjective age (uni- and multidimensional), accelerated aging, health problems, and awareness of age-related gains and losses on up to 14 days of daily diary assessments. Age, gender, education, and baseline health were included as covariates.

Results. Multilevel models showed that the perception of more age-related losses was associated with an exacerbation of the negative association between daily health problems and multidimensional subjective age and accelerated aging. On days with fewer health problems, participants felt younger and felt they were aging more slowly, especially when perceiving more age-related gains.

Discussion. Our findings attest to the importance of both the perception of age-related gains and losses in daily life. Perceiving changes as age-related might be influential in interpreting daily experiences and their impact on developmental outcomes.

Keywords*:* Views of aging, Subjective accelerated aging, Age-related gains, Age-related losses.

3.2 Introduction

Daily Health Problems, Views of Aging, and the Moderating Role of Awareness of Age-Related Changes

Views of Aging (VoA) subsumes several constructs important for lifespan development (Wurm et al., 2017). Subjective age, for instance, refers to the age one feels relative to one's chronological age. It is recognized as a biopsychosocial marker of aging, reflecting people's overall health, well-being, and functioning (Kotter-Gruhn et al., 2015; Stephan et al., 2015). Additionally, subjective age predicts aging-relevant outcomes such as health, well-being, and longevity (Debreczeni & Bailey, 2020; Westerhof et al., 2023). Besides, people may form age identities by reflecting on their aging process regarding how quickly they feel they are aging. Subjective accelerated aging thus refers to how individuals are aware of and evaluate their rate of aging: slowly, fast, or normally. It is, like subjective age, considered to be influenced by social, psychological, and physical conditions (Palgi, 2020). A further important VoA is awareness of age-related changes (AARC, Diehl & Wahl, 2009), which refers to the experience of changes that are attributed to the aging process.

In recent studies, researchers have found meaningful daily within-person variability in subjective age, accelerated aging, and awareness of age-related changes (Kotter-Grühn et al., 2015; Kornadt et al., 2021; O'Brien & Smyth, 2023; Shenkman et al., 2024). In the current study, we investigated daily health problems as predictors of daily VoA and the moderating role of AARC.

(Daily) Health Problems and Subjective Views of Aging

Health matters for people's VoA. For example, bodily problems seem to affect people's subjective age over time (Barrett & Gumber, 2020), and functional health has been shown to predict subjective age over a 10-year period (Hughes & Lachman, 2016). Moreover, health becomes especially relevant with increasing chronological age, as better health is more

strongly associated with a younger subjective age as people get older (Stephan et al., 2012). Less is known about accelerated aging's relation to physical health, but it has been negatively associated with mental health problems and negative affect (Palgi, 2020; Shenkman et al., 2024)). The theoretical framework by Hughes and Touron (2021) emphasizes the importance of the immediate context for a person's subjective age, that is, experiences in their daily lives. Aligned with this theory, studies have demonstrated that daily and momentary experiences, such as daily health problems, influence subjective age (Kotter-Grühn et al., 2015). Still, whether certain experiences are incorporated into people's subjective aging might depend on their awareness of age-related changes.

The Role of Awareness of Age-related Changes

AARC consists of perceptions of daily situations attributed to aging, thereby shaping individuals' aging experiences and identities (Diehl & Wahl, 2009). When reflecting upon one's own aging, it is often losses that come to mind, e.g., loss of health or functionality. Experiencing age-related losses in daily life may activate negative age stereotypes about one's own aging and serve as a vulnerability when facing stressful events (Bellingtier & Neupert, 2016). Perceiving more losses could thus exacerbate the negative impact of daily health problems on VoA by fostering an interpretation as an irreversible sign of aging and by increasing negative affect.

AARC is a multidimensional concept that also encompasses gains related to aging, such as feelings of wisdom and stronger social relationships (Diehl & Wahl, 2024). Perceiving age-related gains might buffer the effects of negative experiences. For instance, gains have been shown to alleviate the negative impact of losses on health outcomes (Windsor et al., 2022). Relatedly, experiencing gains may serve as a buffer against the negative effects of health problems on VoA.

Aims and Hypotheses

The present study investigates whether the association between health problems and VoA is moderated by people's experience of age-related gains and losses. In line with previous research, we expected more health problems to be associated with older subjective age and an accelerated experience of aging. We furthermore expected the association to be amplified on days when participants experience more age-related losses. We also hypothesized that on days when participants experience more age-related gains, the association between daily VoA and health problems would be weaker.

3.3 Methods

Sample and Procedure

The study is part of an international research consortium on the experience of aging in daily life across different cultural contexts (Subjective AGES: Subjective Aging within Global Everyday Ecological Studies). It was approved by the Ethics Review Panel of the University of Luxemburg (ERP-22-086-DACE). Data was collected in Germany from January to April 2023. Participants were recruited through flyer distribution in public spaces, social media, and word-of-mouth. Inclusion criteria were German-speaking, residing in Germany, and aged 50+. Participants answered an initial baseline questionnaire before receiving a link to the daily questionnaire for the next 14 days. They were compensated with a €20 Amazon voucher for participation on more than 10 days and €10 for more than 7 days.

To ensure sufficient power to detect small to medium-sized effects in two-level models, we aimed to recruit 70 participants following the suggested rules of thumb by Arend and Schäfer (2019). Initially, 79 people were invited to participate, but 9 people were excluded due to insufficient data (less than half of study days completed; not completing the baseline questionnaire). During data cleaning, another person was removed due to incomplete

valid data, resulting in a final sample of $N = 69$ participants aged 52-75 ($Mage = 62.72$, $SD = 5.57$, 58% identified as female). We ultimately used $n = 824$ valid daily observations ($M = 11.9$ days, $SD = 1.70$, Min = 9 days, Max = 14 days).

Measures

Subjective age

Subjective age was assessed with a single item and a multidimensional scale. The single item reads: "Many people feel older or younger than their chronological age. How old did you feel in the past 24 hours? (Please respond in years)". Participants' subjective age was subtracted from their chronological age, with negative numbers indicating feeling younger. The scores were outlier corrected by removing scores outside three standard deviations from the mean ($n = 13$ observations, 1.7 %).

Multidimensional subjective age was assessed with the scale by Barak and Stern (1986). Participants rated how old they felt in the past 24 hours regarding their mental/emotional health, physical health, physical appearance, and behavior on a scale from 1 (much younger than my age) to 5 (much older than my age). A mean score was computed for each day from the four variables (Cronbach's alpha across all days = .88), with higher values indicating feeling older.

Subjective accelerated aging

Subjective accelerated aging was assessed with a single item asking participants "In general, I feel that my aging rate in the past 24 hours is: 1 = very slow to 5 = very fast" (Palgi, 2020).

Daily Health Problems

Daily health problems were measured with the Somatic Symptom scale-8 (SSS-8) (Gierk et al., 2014), which consists of 8 items, each representing different symptoms (e.g., back pain, dizziness, and stomach issues). Participants were asked, "In the past 24 hours, how much have you been bothered by any of the following problems?" whereupon participants

responded from 0 (not at all) to 4 (a great deal). Each participant's item scores were aggregated to one sum score representing their daily symptom load (Cronbach's alpha across all days = .79).

Daily Awareness of Age-Related Changes

The daily version was adapted from Brothers et al. (2018) by Neupert and Bellingtier (2017). Participants reported their awareness of age-related gains (10 items) and losses (10 items) during the past 24 hours ("With my awareness of aging in the past 24 hours, I realize that..."). Responses were given on a 5-point Likert scale, where higher scores indicate a greater perception of gains or losses. A mean score was computed for gains (Cronbach's alpha = .94) and losses (Cronbach's alpha = .91).

Covariates

Covariates were assessed on the between-person level in the baseline questionnaire. Participants rated their health on a scale ranging from 1 (not good at all) to 5 (excellent). They indicated their highest level of education from 1) no formal education to 6) a graduate degree. They reported on their gender (1 male, 2 female) and chronological age.

Analyses

We first ran empty models, obtaining intraclass correlations for the daily variables. To test our hypotheses, we ran multilevel multiple regressions with daily health problems (group-mean centered) predicting the three subjective aging measures, respectively.

In the second step, gains and losses (group-mean centered) were added to the models as predictors. To test moderation effects, interaction terms were created by multiplying the centered variables: gains x health problems and losses x health problems. In the third step, we added the interaction terms to the models. Covariates (grand-mean centered) were added on the between-person level in a final model. When moderation effects were significant, we performed simple slopes analyses with a macro provided by Preacher and colleagues (2006).

Descriptive statistics were computed with SPSS 29, multilevel analyses with Mplus 8.11 (Muthén & Muthén, 1998-2024).

3.4 Results

Descriptive Statistics and Bivariate Correlations

Descriptive statistics, bivariate correlations, and intraclass-correlations (ICC) are presented in Table 1. Around 21% of the variation in subjective age resulted from intra-individual variation, whereas accelerated aging showed a higher proportion of variance at the intra-individual level (41%). Gains and losses showed similar variations as subjective age, while health problems showed slightly more variance on the within-person level.

Table 1.

Descriptive statistics and bivariate correlations (between persons) for all study variables.

Variables	*n*	*M (SD)*	ICC	1	2	3	4	5	6	7	8	9
1 HP	840	1.42 (0.52)	.703	-								
2 SAC	735	-2.37 (4.91)	.791	.15*	-							
3 BARAK	822	2.70 (0.60)	.719	.28*	.70*	-						
4 AA	822	1.55 (0.89)	.589	-.17*	.25*	.30*	-					
5 Losses	822	1.68 (0.65)	.822	.59*	.10*	.29*	-.14*	-				
6 Gains	822	2.63 (0.99)	.860	.19*	-.25*	-.25*	-.29*	.39*	-			
7 Gender	824	female 59.1%		.08*	-.03	.03	-.11*	.21*	.31*	-		
8 Age	824	62.76 (5.72)		-.14*	-.08*	-.14*	-.15*	-.43*	-.20*	-43*	-	
9 Education	768	4.76 (1.36)		-.17*	-.24*	-.18*	.05	-.32*	.25*	-.32*	.35*	-
10 Health	824	3.48 (0.76)		-.26*	-.13*	-.27*	.16*	.03	-.12*	.03	-.10*	-.05

Note. HP = health problems; SAC = outlier-corrected subjective age score; BARAK = *multi*-item subjective age score; AA = accelerated aging; Gender, 1 = male, 2 = female; Education, 1 = no formal education, 2 = primary, 3 = secondary, 4 = high school, 5 = applied sciences university diploma, 6 = university degree, 7 = doctorate. * $p < .05$.

Multilevel Regression Analysis

Multilevel regression results are presented in Table 2. Health problems significantly predicted all subjective aging measures across all four models: more daily health problems were associated with older subjective ages and higher subjective accelerated aging.

Subjective Age Difference Scores

Adding losses and gains in the second step did not reveal significant effects on subjective age, nor did entering moderator terms in the third step (Table 2, models 2-3). When including the covariates in the final step, however, the moderation effect of gains on the association between health problems and subjective age became significant (Table 2, model 4). Simple slopes analysis (Fig. 1, Panel A) showed that the perception of age-related gains contributed to a younger subjective age, especially at low levels of health problems.

Multidimensional Subjective Age.

Losses were positively related to multidimensional subjective age: On days with more perceived age-related losses, participants felt older (Table 2, model 3). Adding the interaction terms, the direct effect of health problems was qualified by moderation (Table 2, model 3). Losses exacerbated the effect of health problems on multidimensional subjective age (Fig. 1, Panel B): the association of health problems and feeling older was especially pronounced on days with many perceived age-related losses. These results did not change when covariates were added to the model (Table 2, model 4). Gains significantly predicted subjective age in the final model; participants felt younger on days with more gains.

Subjective accelerated aging

Perceiving more age-related losses was associated with increased feelings of accelerated aging across all models (Table 2, model 2-4). Including the interaction terms yielded a significant moderation effect of losses on the association between daily health problems and subjective accelerated aging (Table 2, model 3-4). Perceiving more losses

exacerbated the effect of daily health problems on subjective accelerated aging (Fig. 3.1, panel C). This effect remained significant when covariates were added to the model. Gains, as well as the interaction of gains with health problems, were unrelated to subjective accelerated aging in the models without covariates but became significant when entering the covariates in the final model (Table 2, model 4). Days with fewer health problems were associated with lower accelerated aging, especially on days with many perceived age-related gains (Fig. 3.1, panel D).

Table 2

Multilevel Regression Analyses Predicting Views of Aging from Health Problems, AARC Losses, AARC Gains, Interaction Terms and Covariates.

Variables	Model 1		Model 2		Model 3		Model 4	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
SAC								
Within								
HP	**1.94 (.49)**	<.001	**1.52 (.41)**	<.001	**1.34 (.51)**	.008	**1.62 (.40)**	<.001
Losses			1.17 (.81)	.148	1.16 (.80)	.145	1.05 (.81)	.194
Gains			-.46 (.43)	.284	-.41 (.51)	.429	-.69 (.50)	.173
HP*Losses					1.53 (1.75)	.383	1.51 (1.08)	.161
HP*Gains					-.94 (1.25)	.452	**1.70 (.85)**	.045
Between								
Gender							-1.68 (1.38)	.223
Age							-.08 (.14)	.570
Education							**-.97 (.40)**	.015
Health							-.96 (.76)	.204
BARAK								
Within								
HP	**.40 (.07)**	<.001	**.32 (.06)**	<.001	**.25 (.06)**	<.001	**0.32 (.06)**	<.001
Losses			**.24 (.07)**	.001	**.21 (.07)**	.002	**0.22 (.07)**	.001
Gains			-.06 (.04)	.156	-.07 (.05)	.125	**-0.10 (.05)**	.028
HP*Losses					**.79 (.29)**	.008	**0.45 (.16)**	.005
HP*Gains					-.12 (.19)	.520	0.18 (.15)	.237
Between								
Gender							-0.08 (.13)	.553
Age							-0.01 (.01)	.259
Education							-0.07 (.04)	.104

Health							**-0.22 (.08)**	.004
AA								
Within								
HP	**.62 (.10)**	<.001	**.44 (.10)**	<.001	**.32 (.12)**	.008	**.41 (.11)**	<.001
Losses			**.52 (.12)**	<.001	**.46 (.12)**	<.001	**.47 (.11)**	<.001
Gains			-.06 (.06)	.314	-.11 (.06)	.086	**-.13 (.06)**	.030
HP*Losses					**1.46 (.52)**	.005	**.59 (.21)**	.006
HP*Gains					-.01 (.31)	.968	**.32 (.13)**	.019
Between								
Gender							**.41 (.18)**	.021
Age							-.01 (.02)	.638
Education							.03 (.07)	.652
Health							**-.26 (.12)**	.037

Note. b = unstandardized regression coefficient. SE = standard error. SAC = Outlier-corrected Subjective Age score: BARAK = Multi-item Subjective Age score; AA = Accelerated Aging. Model 1: within-level only with Health Problems as a predictor. Model 2: within-level only with Health Problems, AARC Losses, and AARC Gains as predictors. Model 3: within-level only with Health Problems, AARC Losses, AARC Gains, and Moderator terms as predictors. Model 4: Two levels with Health Problems, AARC Losses, AARC Gains, Moderator terms, and covariates as predictors. Values significant at p <.05 in bold font.

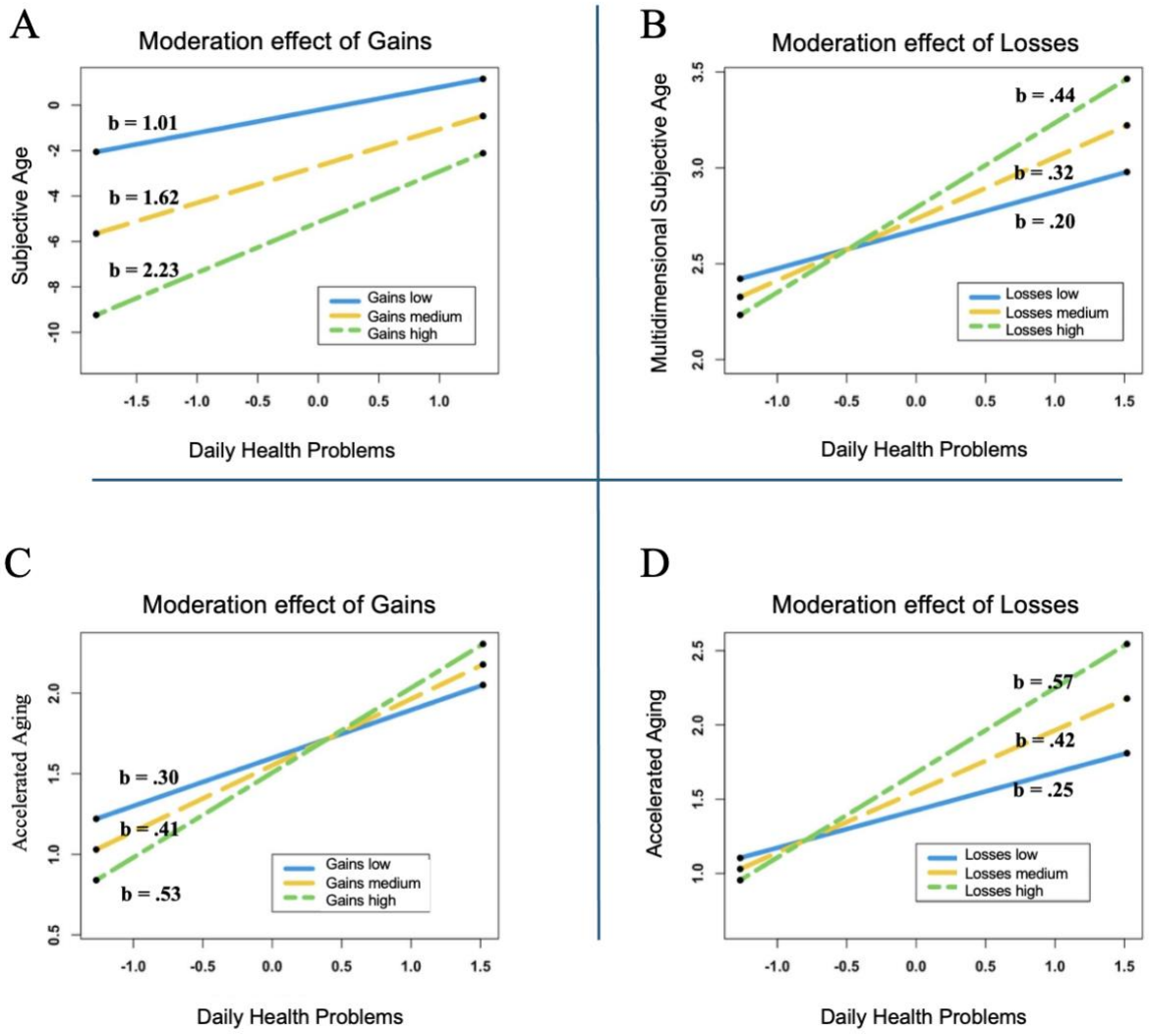

Figure 3. 1. Simple slopes analysis for significant moderation effects of awareness of age-related gains and losses on the relationship of health problems to different subjective views on aging indicators in models with covariates. b = unstandardized regression coefficients. Results significant at $p < .05$ are presented in bold font.

3.5 Discussion

The current study used daily-diary data to examine the effect of AARC on the association between daily health problems and measures of VoA (subjective age and subjective accelerated aging). Consistent with previous studies (Kotter-Grühn et al., 2015), more daily health problems were related to more negative VoA on a daily level. Our results extend previous research by illustrating the role of AARC in subjective age and subjective accelerated aging and their relation to health problems. Experiencing more losses on a given day was related to feeling older and aging faster, while experiencing more gains was related to feeling younger and aging slower, but was not associated with the unidimensional subjective age measure. In line with our hypotheses, these main effects were qualified by significant interactions between AARC and daily health problems. The perception of losses seems to pose a special risk on days with more health problems. Experiencing more losses on a given day is associated with increases in the negative impact of health problems on both multidimensional subjective age and subjective accelerated aging. Their effects are less pronounced on days when people perceive fewer age-related losses. Losses may increase people's sensitivity to signs of aging; experiencing more losses likely activates mechanisms of stress (Bellingtier & Neupert, 2016), aging stereotypes (Wettstein et al., 2022), or lower control beliefs (Zhang & Neupert, 2020) and, as such, may provide a somber backdrop for interpreting one’s aging.

Perceiving more gains on a given day buffered the negative effect of health problems on unidimensional subjective age and subjective accelerated aging at low levels of health problems. With increasing health problems, the buffering effect of gains became less pronounced. This is in line with longitudinal studies showing that the association of better health with younger subjective age is, for example, reinforced by positive social comparison (Hughes & Lachman, 2016). When people are more aware of their gains, they may tend to compare themselves more favorably to others, reinforcing the association of fewer health

problems and feeling younger. It seems that gains are especially relevant when one feels well overall, whereas losses exacerbate the effects when people report more negative experiences, such as health problems.

To our knowledge, our study is the first to examine how associations between daily health problems and VoA are affected by daily changes in AARC- gains and losses. There are still some considerations to keep in mind while interpreting our results. Firstly, while our results were overall in line with expectations, they also highlight the distinct nature of the VoA constructs and speak for wise considerations when deciding on subjective aging measures. Results from the moderation analyses also suggest that the different VoA measures are at least partly distinct, and that subjective accelerated aging may be an under-studied construct as both AARC gains and losses seem to affect how quickly people feel that they are aging. Relatedly, future research should explore how the specific scale domains of the multidimensional subjective age measure and AARC, such as health, relate to health problems to increase our understanding of the underlying mechanisms of subjective aging processes.

3.6 Conclusions

Changes in daily health problems are associated with short-term variations in VoA. AARC plays a role in how these health problems are related to VoA, with distinct effects of gains and losses. This study contributes to the growing awareness of short-term variation in VoA, which might open the door to potential interventions for raising awareness about aging in daily life.

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Chapter 4 – Momentary Physical Activity, Subjective Age, and the Moderating Role of Pain

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The subsequent article has been published as follows:

Tingvold, M., Notthoff, N., Borgmann, L., & Kornadt, A. E. (2025). Momentary physical activity, subjective age, and the moderating role of pain. *European Journal of Ageing*, *22*(1), 1. https://doi.org/10.1007/s10433-024-00836-8

The online supplemental material is included in the appendix.

4.1 Abstract

Subjective age, that is felt age compared to chronological age, is an important predictor of health and well-being in later life. It can fluctuate from day to day and from one moment to another. Previous cross-sectional and macro-longitudinal studies have shown that feeling younger is related to physical fitness and exercise. Yet, there is limited knowledge on the effects of physical activity on subjective age in daily life and moderators of this association. We thus aim to investigate the association of momentary physical activity with momentary subjective age, expecting that more activity is related to feeling younger. We further expect that concurrent pain experience attenuates this relationship. $N = 54$ participants aged 50-62 years (*Mage* = 56.1 years, 75% female) wore chest-sensors measuring their physical activity (step count, movement acceleration) for one week and reported on their subjective age five times per day. Multilevel regression analyses revealed between and within-person variation in momentary subjective age (ICC = .74), pain (ICC = .63) and physical activity (ICC Moac30 = .078, steps30 = .053). Pain emerged as a consistent predictor of momentary subjective age ($b = 4.64$, $p = .000$) whereas results were mixed for the physical activity measures. No significant moderating effect of pain was observed on the relationship between physical activity and subjective age. Our study shows the importance of pain experiences for momentary subjective age, whereas the role of momentary physical activity needs further exploration.

Key words: Subjective age, pain, physical activity, midlife, ambulatory assessment

4.2 Introduction

Momentary Physical Activity, Subjective Age, and the Moderating Role of Pain

An increasing number of people is living to very advanced ages, and consequently, we need to understand and promote how people can age well. Subjective age, i.e., the age people feel compared to their chronological age, is an important variable in this regard, being both predictive of developmental outcomes, and reflecting several biopsychosocial aging processes (Kotter-Gruhn et al., 2015; Montepare, 2009; Weiss & Weiss, 2019). Long term and experimental dynamics of subjective age have been well studied, but less is known about the dynamics of subjective age in participants' daily life. Subjective age is associated with physical activity, which is considered important for healthy aging (e.g. (Baker et al., 2009)). Engaging in less physical activity is, for example, associated with feeling older over time (Stephan, Sutin, Wurm, et al., 2020). The relation between physical activity and subjective age might, however, be dependent on other factors, such as the experience of pain. More pain tends to increase the age people feel (Barrett & Gumber, 2020; Wettstein et al., 2024) and to impact daily variations in subjective age (Kotter-Grühn et al., 2015). In the current study, we thus investigate how objective and subjective measures of physical activity are associated with the subjective aging experience of middle-aged adults, and whether the experience of pain affects this relationship.

Subjective Age and Physical Activity in Later Life

Subjective age has become an important factor in aging research and in the study of "successful aging" (Sabatini et al., 2024). Starting in their late twenties, most people feel younger than their chronological age, and this experience persists up to advanced ages (Pinquart & Wahl, 2021). A younger subjective age has been longitudinally and cross-sectionally related to a diverse set of positive health outcomes in later life such as better

physical and psychological health (Alonso Debreczeni & Bailey, 2020; Westerhof et al., 2023). Physical activity is one important mediator of this relationship, as participants who feel older also report being more inactive (Stephan et al., 2018).

In addition to being a predictor of developmental outcomes, however, subjective age is also conceptualized as a biopsychosocial marker of aging, as the age people feel is assumed to reflect their overall health, well-being, and functioning (Kotter-Gruhn et al., 2015; Stephan et al., 2015). Thus, the relationship of subjective age with many indicators of health and well-being, such as, physical activity, is likely reciprocal: Bodily sensations, and physical functioning influence people's felt age (e.g. Barrett and Gumber 2020). People experiencing health through physical activity likely feel more positive about their aging process and therefore feel younger (Stephan, Sutin, Wurm, et al., 2020). Social comparison processes might also play a role as people who consider themselves as more active and physically stronger than their peers are likely to feel younger (Hughes & Lachman, 2016; Stephan et al., 2013).

Several studies have provided evidence for the association of physical activity and subjective age (e.g. (Alonso Debreczeni & Bailey, 2020; Chen et al., 2018; Heimrich et al., 2022; Stephan, Sutin, Wurm, et al., 2020; Wang et al., 2022). For instance, in a cross-sectional study, Heimrich et al. (2022) found that engaging in sports more frequently was related to feeling younger in a representative German sample. Longitudinally, Stephan, Sutin and Terracciano (2020) found that engaging in more physical activity predicted feeling younger 8-20 years later.

In sum, there are theoretical and empirical arguments for a reciprocal association between subjective age and physical activity, and specifically an effect of physical activity on felt age. However, evidence is limited in terms of short-term variations in subjective age, as few studies so far have investigated this relationship in real-life settings.

Subjective Age and Physical Activity in Daily Life

In everyday life, adults come across situations that make their age more salient. The course of a day holds a wide range of changing situations, sensitivities and personal interpretations, and a person can go from a moment of feeling old to one of feeling younger. This is framed in the contextual model of Hughes and Touron (2021) which describes subjective age within people's momentary context. Thus, increasing the focus on the daily life context is important for understanding the dynamics underlying the construction of subjective age.

Indeed, subjective age varies in daily and momentary time frames. Kotter-Grühn et al. (2015), for instance, found considerable within-person variability of subjective age in a daily-diary study and demonstrated that intra-individual increases in subjective age were predicted by health problems, stress, and negative affect. On a more fine-grained timeline, Kornadt et al. (2021) found that 25% of the variability in momentary subjective age could be attributed to within-person variation, with an average variation of 3 years from one measurement occasion to the next. Again, there are both theoretical arguments and empirical studies indicating that subjective age shows meaningful short-term fluctuations Understanding these fluctuations gives insight into the process shaping subjective aging experiences in daily life and contributes to a better understanding of their translation into long-term developmental outcomes (Hughes & Touron, 2021).

Relatedly, exploring physical activity in daily life is crucial for understanding its intrapersonal dynamics and associations to various (age-related) outcomes (Reichert et al., 2020). Notthoff et al. (2018), for instance, compared the relationship of subjective age and walking speed (as an indicator of physical functioning) in the laboratory and in real life and found that people who felt younger did indeed walk faster. This was however only the case in the laboratory and not in real life. Thus, the effects of physical activity on people's subjective age seem to depend on how and where it is measured.

Furthermore, people rely on heuristics when reporting on past events, and these reports are, consequently, usually biased (Burchartz et al., 2020; Gilovich et al., 2002). In particular, physical activity measures are often influenced by social desirability (Brenner & DeLamater, 2014). Leveraging objectively measured physiological data provides an ecologically valid measure of within-person processes over time (Reichert et al., 2020). Additionally, subjective and objective measures of physical activity have been estimated to only covary about 16 percent (Adamo et al., 2009), indicating that subjective and objective measures can provide different information about individual processes.

Taken together, assessing both subjective age and physical activity in daily life provides us with ecologically valid data from people's daily experiences, and allows us to investigate the association of both variables on intra- and interpersonal levels. Recently, Schmidt et al. (2024) demonstrated that taking more daily steps was associated with younger subjective ages in a sample of older adults who reported on their subjective age and wore a sensor measuring their physical activity. However, they assessed subjective age only on a daily level, and did not investigate further moderating effects.

Subjective Age and Physical Activity – The Role of Pain

Both physical activity and subjective age are anchored in bodily experiences. These internal experiences could thus influence their association by providing a shared context. This idea is also represented in the theoretical framework by Hughes and Touron (2021), stating that the internal condition of the individual likely affects their felt age. Pain represents such a bodily condition and is indeed associated with both physical activity and subjective age (Kotter-Grühn et al., 2015; Naugle & Riley, 2014).

Some studies have shown association between physical activity and pain. Different levels of pain are related to lower probability of engaging in physical exercise (Axon & Maldonado, 2023). An ambulatory-assessment study on the momentary association between physical activity and pain found that when participants took more steps than usual before the

prompt, they were more likely to experience pain at the prompt (Davis et al., 2023). Moreover, physical activity can also have negative associations with pain as moderate to vigorous activity can reduce the symptoms from chronic pain (Naugle & Riley, 2014). A recent review on ambulatory assessment studies examining the association between physical activity and pain showed that the association is complex as results across studies are highly heterogenous (Tynan et al., 2024). Thus, the association of physical activity and pain needs further exploration.

Empirical findings also relate pain to subjective age. Kotter-Grühn et al. (2015) found that pain contributed to the prediction of daily within-person variation in subjective age in a daily context; the more pain participants experienced, the higher their subjective age. Additionally, Barrett and Gumber (2020) found that everyday body problems such as pain affect people's age identity, making them feel older. Likewise, associated with relatively older subjective ages (Booker et al., 2020). Longitudinally, more pain has been associated with older felt age on both between- and within-person levels (Wettstein et al., 2024). Altogether, this shows a possible direct effect of pain on subjective age.

Besides, by providing a specific context pain likely moderates the effect of physical activity on subjective age. It is plausible that for adults in late middle age, being more physically active is associated with feeling younger, but this may be contingent on concurrent pain experience. First, increased pain during exercise may remind adults that they are getting older (Karp, 1988). This is especially relevant in late middle age, which is characterized by a higher frequency of major bodily events like menopause (Talaulikar, 2022), onset of illnesses like strokes (Seshadri et al., 2006) or cancers (Yancik, 2005), and a decrease of muscle mass (Yancik, 2005). Second, increased pain sensations during physical activity may activate comparisons to younger ages when physical activity was not associated with pain, and thus, increase felt age. Finally, more pain experiences during exercise might activate such old age stereotype that pain is a normal part of physical activity, and thus increase subjective age.

In sum, physical activity and subjective age are both associated with the experience of pain. However, we do not know much about the momentary relationship between these variables. There are theoretical foundations in place that offer possible frameworks for how pain can play a role in the subjective aging experience, yet there are few studies exploring their associations.

Aims and Hypotheses

The current study aims to explore how momentary subjective age is associated with objectively measured physical activity in a daily context. We expect people's physical activity to be associated with how old they feel: if people are more active at a given moment, the younger they feel consecutively. We expect that if people experience more pain than usual, the relationship between physical activity and subjective age is reversed, i.e., more physical activity with a higher concurrent pain experience should increase subjective age.

4.3 Methods

Sample

Data collection took place from June to December 2021. The sample consisted of N = 54 participants aged 50-62 (*Mage* = 56, *SD* = 3.88), where 74% were female, 24% male, and one participant reported their gender as "other". Participants were recruited through online and paper distribution of flyers in social media, local senior centers, hairdressers, and cafés. The flyer advertised the study as focusing on participants' experience of aging and explicitly mentioned that physical activity would be measured. Participation requirements were age 50-65 and reading capacity in French or German. Exclusion criteria were physical walking disabilities or known heart conditions (to ensure validity of the sensor measurement). Sample size selection followed recommendations of Arend and Schäfer (2019) to have a sample size of 50 at level-1 for detecting medium-sized effects. A total of 52 people were included in the

final multilevel analysis as two participants were missing sensor data and were therefore excluded.

Procedure

All participants came to an initial laboratory assessment where they signed consent forms, completed baseline questionnaires, and were fitted with the ECG-sensor for physiological measurements. They were informed that the sensor would measure their heart rate, activity and body temperature throughout the study. Participants received information on usage of the sensor and were guided to install and use a mobile application for the ecological momentary assessment (EMA) sampling scheme (see below). A demonstration of the application scheme was performed. For participants whose phones did not match the requirements for the app, or those who did not want to use their own phones, we provided a tablet for the duration of the study (Lenovo M7). On the 7 days following the baseline assessment, participants received five EMA prompts per day at 09, 12, 15, 18 and 21 o'clock, respectively. After this week, participants returned with the sensor and tablet and answered a short questionnaire about their experience of participating in the study. Participants received three multipurpose vouchers with a combined value of 90 euros (two vouchers at initial session and one at final session) for their participation as well as personalized feedback on their personality and physical activity, which was sent to them after data were processed. The study was approved by the Ethics Review Panel of the University of Luxemburg (*ERP 21-016 SADIE)*.

Measures

Data were collected in three ways: a baseline assessment consisting of paper-pencil questionnaires focusing on general information and trait measures of subjective age and physical activity, an EMA displayed on participants' phone/tablet, focusing on momentary subjective experiences (subjective age and pain), and a continuous measure of physiological

activity measured by a chest-worn sensor. Metabolic equivalent of task (MET), body mass index (BMI), and sociodemographic information were assessed at baseline and used as control variables. 46.3% of participants answered the questions in French and 53.7% in German.

Baseline Questionnaire

Metabolic Equivalent of Task – MET

Participants' self-reported overall activity level was assessed at baseline with the International Physical Activity Questionnaire - short form (IPAQ-SF, (Craig et al., 2003)). Participants reported how many minutes of moderate and vigorous activity, walking and sitting they engaged in over the past 7 days. The reported minutes on the different activity intensities were used to calculate the overall metabolic equivalent of task (MET) scores according to the IPAQ scoring manual. One MET represents the energy spent while being sedentary, moderate activity includes a range of 3-6 MET's, while 6 METs and above are categorized as vigorous activity. For this study, the average MET scores for the last 7 days were used in the analyses. MET scores were Box Cox tranformed, to correct for skewed data (Malik et al., 2018).

BMI

Participants reported their height and weight which were used to calculate participants' BMI scores, which were then Box Cox transformed.

Ecological Momentary Assessment

Questionnaires on tablets/smartphones were presented through the MovisensXS Platform (version 1.5) and the app installed on the tablets (Movisens, GmbH, Karlsruhe, Germany). Participants were invited to answer questions at five fixed timeslots per day. Momentary subjective age and pain experiences were assessed as well as indicators of well-being, affect, activity, and social interaction (which are not relevant for the present study).

State Subjective Age

Momentary felt age was measured asking participants “Many people feel younger or older than they actually are. This feeling younger or older can fluctuate from day to day or even within a day. Apart from your actual age, how old do you feel at the moment? (Age in years).” Participants manually inserted a number indicating how old they felt in the given moment. Subjective age was calculated by subtracting this number from participants’ chronological age, so that a negative number would indicate feeling younger. Scores three standard deviations above and below the mean of the overall sample were removed (more than -29.48 years younger or more than 15.28 years older, this included 2.2% of scores).

Pain

The subjective momentary experience of pain was assessed by asking people “How much pain or physical discomfort do you experience right now?”. Participants reported their pain experience on a sliding scale ranging from very bad to very good providing a variable ranging from 0-100. Pain was Box Cox transformed.

Sensor Data

Participants were invited to wear sensors measuring physiological data during the week of the study. The physiological data were recorded with Movisens ECG4Move sensor (Movisens GmbH, Karlsruhe, Germany). The output rate of the sensor is 64 Hz/s, and it has a measurement range of +-16g (gravity units). The sensor was chest-worn with a belt. Participants were instructed to always wear the sensor except during showers. Data was processed with the Movisens Analyzer software offering output of different physiological indicators with 60 seconds intervals. For the current study, we used movement acceleration and step count as measures of physical activity. The data of interest were imported into SPSS 29, and intervals of 10, 20 and 30 minutes before participants finished the next EMA-questionnaire were extracted for step count and movement acceleration. As there is little research and no consistent recommendation to choose the time intervals, we refer to acute

exercise which is defined as bouts of exercise with a duration of 1-60 minutes (Basso & Suzuki, 2017) and investigated these three different time frames separately to increase the robustness of our findings.

Movement Acceleration

Movement acceleration measures the person's physical activity by detecting movement intensity and direction. The movement acceleration variable refers to each person's average score (Moac10, Moac20, Moac30, respectively). A higher score indicates that a person has had higher intensity in their movement during the measured time interval. Data for each time interval were checked for outliers (by a visual examination of the data distribution), and correlational analysis were conducted with and without the most extreme cases, which revealed no significant impact of the outliers, and all scores were kept for further analysis. Furthermore, a Box Cox transformation (Malik et al., 2018) was performed due to an initial positive skew of the distribution (resulting in a normal distribution).

Step Count

Step count refers to the number of steps a person is walking in the given interval. Step count was computed summing up the number of steps for the given time interval (Steps10, Steps20, Steps30), and checked for extreme cases (by a visual examination of plots). Removing these extreme values, however, greatly reduced the *N* of analyses ($N = 1508$). Thus, multiple transformations were tested and a log10+10 transformation provided the best distribution, adjusted for a positive skew of the scores and reduced the impact of the most extreme scores. It was therefore performed on all three time-intervals ($N = 1851$).

Analyses

As a first step, descriptive statistics and bivariate correlations were computed with SPSS 29, investigating means and bivariate relationships between variables. To test for variance attributable to between- and within-person differences, we computed intraclass

correlations (ICCs). The higher the ICC, the more variance is associated with the between-person level (Rönnkö, 2020).

To investigate our main research questions, we ran multilevel regression models with Mplus 8 (Muthén and Muthén, 1998-2023), predicting momentary subjective age by the respective predictor variables. We ran models separately for each of the six physical activity variables. Each model included one of the six physical activity variables. All variables used on the within-person level only were group-mean centered, all variables used on the between-person level only were grand mean centered (Enders & Tofighi, 2007). For variables used at both levels, variables were not centered a priori, as in this case, Mplus automatically applies latent group mean centering (Asparouhov & Muthén, 2019).

We first computed models containing only the within-person level (L1), and predictor variables (group-mean centered) were entered stepwise: 1) physical activity (movement acceleration or step count), 2) physical activity and pain, 3) physical activity, pain, and the moderation term. In a second step, both the within-person (L1) and between-person (L2) levels were included in the analysis. Again, predictors were included stepwise: 1) physical activity on both levels, and pain on both levels, 2) physical activity, pain, and the moderation term, all on both levels, 3) physical activity, pain and the moderation term on both levels, including the between person covariates BMI, MET, and age on level 2 (grand mean centered). The equations for the final models are as follows:

Level 1 Model:

$$\mathrm{SSA}_{ij} = \beta_{0j} + \beta_{1j} \cdot \mathrm{Physical\ Activity}_{ij} + \beta_{2j} \cdot \mathrm{Pain}_{ij} + \beta_{3j} \cdot \mathrm{Moderation}_{ij} + e_{ij}$$

Level 2 Model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} \cdot \mathrm{Physical\ Activity}_{j} + \gamma_{02} \cdot \mathrm{Pain}_{j} + \gamma_{03} \cdot \mathrm{Moderation}_{j} + \gamma_{04} \cdot \mathrm{Age}_{j} + \gamma_{05} \cdot \mathrm{BMI}_{j} + \gamma_{06} \cdot \mathrm{MET}_{j} + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} \cdot \text{Physical Activity}_j + \gamma_{12} \cdot \text{Pain}_j + \gamma_{13} \cdot \text{Moderation}_j + \gamma_{14} \cdot \text{Age}_j + \gamma_{15} \cdot \text{BMI}_j + \gamma_{16} \cdot \text{MET}_j + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21} \cdot \text{Physical Activity}_j + \gamma_{22} \cdot \text{Pain}_j + \gamma_{23} \cdot \text{Moderation}_j + \gamma_{24} \cdot \text{Age}_j + \gamma_{25} \cdot \text{BMI}_j + \gamma_{26} \cdot \text{MET}_j + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31} \cdot \text{Physical Activity}_j + \gamma_{32} \cdot \text{Pain}_j + \gamma_{33} \cdot \text{Moderation}_j + \gamma_{34} \cdot \text{Age}_j + \gamma_{35} \cdot \text{BMI}_j + \gamma_{36} \cdot \text{MET}_j + u_{3j}$$

4.4 Results

Preliminary and Descriptive Statistics

An overview of descriptive statistics, bivariate correlations and ICCs is displayed in Table 1. In terms of associations between variables, between-person correlations revealed that momentary subjective age and all three movement acceleration measures were significantly correlated: Moac10 at r = -.13 (p < .001), Moac20 at r = -.14 (p < .001*),* and Moac30 at r = -.11 *(*p = .001). Momentary subjective age was further unrelated to step count measures of 10 and 20 minutes: Steps10 r = -.00 (p = .896), Steps20 r = -.01 (p = .564), but did significantly relate to step count of 30 minutes: Steps30, r = -.04 (p = .035). Momentary subjective age was significantly correlated with pain (r = -.57, p <.001), and it was also correlated with baseline activity levels: MET, r = -.37 (p <.001). Pain was negatively correlated with all physical activity measures.

In line with previous work (Kornadt et al., 2021), 25% of the variability in momentary subjective age could be attributed to within-person variation (ICC = .74). Nine participants had zero variation in their momentary subjective age, meaning that they reported the same age at every measurement. For all time intervals, variability in movement acceleration was mostly within-person (ICCs = .07-.08, Table 1), indicating that the variance does not change drastically depending on the time scale used. This was similar for the three step-count measures with ICCs of .05 for all time intervals (Table 1). Finally, the ICC for pain was .63

which means that around 40% of the variation in pain could be explained on the within-person level.

Table 1

Descriptive statistics and bivariate correlations for all study variables. Between-person correlations are displayed below the diagonal, within-person correlations.

Variable	*n*	*M (SD)*	*ICC*	1	2	3	4	5	6	7	8	9	10	11
1 SSA	2343 (54)	-6.90 (6.60)	.741	-										
2MOAC10	2256 (52)	.50 (.29)	.072	-.13*	-									
3 MOAC20	2256 (52)	.50 (.29)	.078	-.14*	.98*	-								
4 MOAC30	2256 (52)	.50 (.29)	.078	-.11*	.95*	.98*	-							
5 Steps10	2256 (52)	1.56 (.56)	.046	-0.0	.84*	.82*	.77*	-						
6 Steps20	2256 (52)	1.80 (.64)	.052	-.01	.86*	.88*	.84*	.96*	-					
7 Steps30	2302 (52)	1.98 (.66)	.053	-.04*	.84*	.87*	.88*	.89*	.95*	-				
8 Pain	2343 (54)	.50 (.28)	.631	.57*	-.25*	-.28*	-.33*	-.13*	-.15*	-.19*	-			
9 MET	1936 (45)	.50 (.29)		-.37*	.18*	.23*	.23*	.18*	.23*	.22*	-.30*	-		
10 AGE	2343 (54)	56.02 (3.88)		-.29*	-0.01	-.01	-0.04	-.07*	-.06*	-.08*	-.05*	.06*	-	
11 BMI	2343 (54)	.50 (.29)		.36*	-.18*	-.18*	-.20*	-.17*	-.18*	-.18*	.30*	-0.26*	-.08*	-

Note. SSA, State subjective age; Moac10, Movement acceleration 10 minutes; Moac20, Movement acceleration 20 minutes, Moac30, Movement

acceleration 30 minutes; Steps10, Step count 10 minutes; Steps20, Step count 20 minutes; Steps30, Step count 30 minutes, Pain, Momentary pain; MET, Metabolic equivalent of task; BMI, Body mass index. N refers to the within-level units of analyses, the N in brackets to the between-level

units of analyses. * $p < .05$.

Momentary Physical Activity and Momentary Subjective Age

As a first step, momentary physical activity measures were entered as predictors of momentary subjective age. For all three time-intervals, movement acceleration significantly predicted momentary subjective age (Table 2, Model 1, see Appendix Table A4.3 and A4.4 for the 20- and 30-minute intervals). People who moved more than usual in the given timeframe reported feeling younger at the following prompt compared to. This effect did not hold when pain was included in the models (Table 2, Model 2). None of the step count measures reached significance (Table 5, Model 1, see Appendix Table A4.6 and A4.7 for 20- and 30-minute intervals). These findings partly support our hypothesis: if people are more active in a given moment, they feel younger subsequently.

In the second step, we created two-level models with between-person predictors. Pain remained a significant predictor of momentary subjective age on the within-person level, while physical activity measures remained non-significant in the two-level models (Table 2, Model 4, see Appendix Tables A4.3, A4.4, A4.6 and A4.7- for 20- and 30-minute intervals, respectively). The final models, including covariates, showed that MET was negatively associated with momentary subjective age, indicating that people who in general report being more active also report feeling younger. BMI was positively related to subjective age, indicating that the higher the BMI, the older people feel. Age was negatively related to momentary subjective age, indicating that the higher the chronological age, the younger people feel.

The Moderating Role of Momentary Pain

To test the hypothesis that the experience of pain moderates the relationship between physical activity and subjective age, the interaction term for pain and physical activity was entered into the models (Tables 2 and 5, and Appendix Tables 3, 4, 6, and 7, models 3, 5 and

6, respectively). Movement acceleration became non-significant when including pain in the models whereas pain was a consistent predictor of subjective age in all models: in moments when participants experienced more pain than usual, they felt older. The moderating effect of pain on the relationship between physical activity and subjective age was not significant in any of the models. The effect of pain on momentary subjective age on level-1 remained significant also in the two-level models and when covariates were included (Table 2 and 5, and Appendix Tables 3, 4, 6 and 7, models 4, 6 and 7).

Table 2

Multilevel Regression Analyses Predicting Momentary Subjective Age from Movement Acceleration (10-minute interval) , Pain, Interaction Term and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Moac10	**-.90 (.40)**	**.026**	-.75 (.41)	.071	-.74 (.42)	.078	-.75 (.41)	.070	.15 (2.41)	.949	.24 (2.37)	.918
Pain			**4.62 (1.03)**	<.001	**4.63 (1.04)**	<.001	**4.62 (1.03)**	<.001	**5.38 (2.42)**	.026	**5.45 (2.38)**	.022
Moderation					- 1.30 (3.69)	.725			- 1.68 (4.30)	.696	-1.83 (4.21)	.662
Between												
Moac 10							- 1.03 (9.31)	.912	13.48 (16.43)	.412	28.48 (26.978)	.291
Pain							**14.78 (3.81)**	<.001	**25.98 (11.02)**	.018	30.01 (36.26)	.130
Moderation									- 25.63 (22.67)	.258	- 41.50 (41.87)	.322
BMI											3.72 (2.29)	.105

MET											**-5.12 (1.98)**	.009
Age											**-0.314 (.14)**	.020
$R2_{within}$	.005	.241	.054	.001	.054	.002	.055	.001	.076	.412	.079	.413
$R2_{between}$							.318	.001	.664	.005	.847	<.001

Note. b = unstandardized regression coefficient. SE = standard error. Values significant at p <.05 are in bold. Model 1: within-level only with movement acceleration. Model 2: within-level only with movement acceleration and pain. Model 3: within-level only with movement acceleration, pain and moderation. Model 4: two-level model with movement acceleration and pain, Model 5: two-level model with movement acceleration, pain and moderation. Model 6: two-level model with movement acceleration, pain, moderation, and covariates.

Table 5

Multilevel Regression Analysis Predicting Momentary Subjective age with Step Count (10-minute interval), Pain, the Interaction Term and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Steps10	-.22 (.17)	.184	-.17 (.18)	.325	-.17 (0.18)	.326	.17 (.18)	.327	.31 (.98)	.748	.33 (.97)	.733
Pain			**4.65 (1.03)**	<.001	**4.65 (1.02)**	<.001	**4.65 (1.03)**	<.001	**5.94 (2.96)**	.044	**5.98 (2.93)**	.041
Moderation					.55 (1.62)	.737			-.96 (1.83)	.601	-.98 (1.81)	.587
Between												
Steps10							3.00 (7.09)	.673	7.38 (8.13)	.364	13.50 (8.60)	.117
Pain							**15.02 (3.72)**	<.001	**23.54 (7.18)**	.001	25.29 (10.68)	.018
Moderation									-6.01 (4.44)	.176	-9.64 (7.17)	.179
BMI											4.08 (2.59)	.114

MET											**-5.06 (2.07)**	.015
Age											**- .30 (.13)**	.027
R2within	.001	.499	.052	.004	.052	.004	.053	.004	.096	.445	.098	.439
R2between							.329	.001	.596	.000	.767	<.001

Note. b = unstandardized regression coefficient. SE = standard error. Values significal at p <.05 are in bold. Model 1: within-level only with step count. Model 2: within-level only with step count and pain. Model 3: within-level only with step count, pain and moderation.

4.5 Discussion

In the current study, we investigated the association of subjective age and physical activity in participants' daily life, and whether the experience of pain could alter this relationship. By combining ambulatory assessments and physiological sensor measures, we included both subjective and objective indicators of people's daily life experiences and the investigation of inter- and intrapersonal variation. We built on previous work relating subjective age and physical activity (Heimrich et al., 2022; Schmidt et al., 2024; Stephan, Sutin, & Terracciano, 2020) and demonstrated a possible short-term relation between movement acceleration and momentary subjective age. No significant association was found between step count and momentary subjective age. Furthermore, pain did not moderate the association of physical activity and momentary subjective age but emerged as a significant predictor of momentary subjective age across all within-person models, even when controlling for between-person variability: in moments of more pain than usual people tend to feel older.

The Association of Physical Activity and Subjective Age

In our study, movement acceleration was negatively related to momentary subjective age, indicating that more movement than usual goes along with a younger subjective age which is in line with previous findings (Heimrich et al., 2022; Stephan, Sutin, & Terracciano, 2020). Findings were weaker for step count, which showed a small, between-level, bivariate relation to subjective age in the larger time interval. In the initial within-level regression analysis, movement acceleration predicted momentary subjective age, whereas step count did not. This is in contrast to previous findings by Schmidt et al. (2024), who found significant associations between activity measures and subjective age, albeit on the daily and not momentary level and in a sample with a broader age range.

Including the two activity measures allows for a broader comparison across diverse methodologies in the field (Burchartz et al., 2020). Our results show that the means of measurement as well as the timeline of assessment may be crucial for discovering important relations. Although both variables are indicators of physical activity, they differ in qualitative aspects. Step count provides an apprehensible concept of physical activity but informs less about underlying efforts. Movement acceleration represents activity intensity: the quicker one's movements, the higher the intensity. Steps and movement acceleration could thus represent physical activity performed for different purposes: higher movement acceleration likely represents structured exercise, more steps likely a broader range of daily life activities. Taken into consideration, a certain intensity might be needed for physical activity to impact felt age.

The initial positive association between movement acceleration and subjective age did not hold when including pain and covariates. Drawing from similarities with research on acute exercise, the timing of measures might affect the outcome. Studies have found that physical activity is associated with negative affect immediately after exercise, but if a break is included after the exercise and before the affect measurement, physical activity is associated with positive affect (Reed & Ones, 2006).

Pain and its Momentary Association with Subjective Age

To the best of our knowledge, no previous studies have examined the relationship between momentary physical activity, pain, and subjective age. On the within-person level, we found a strong association between pain and subjective age, which is in line with previous research (Barrett & Gumber, 2020; Booker et al., 2020; Kotter-Grühn et al., 2015). People felt older in moments of more pain than usual, compared to moments with less pain. Pain experience seems to be a bodily reminder of one's age, as bodily pain is associated by many with getting older (Barrett & Gumber, 2020). Furthermore, the experience of pain might go

along with the experience of stress (Abdallah & Geha, 2017), which has consistently been shown to increase subjective age (e.g. (Kornadt et al., 2022)). Future studies should further explore this relationship to investigate whether pain management might be effective in improving subjective aging experiences.

Despite this relation of pain to subjective age, our hypothesis that pain would moderate the relationship between them was not supported. There may be several reasons for this outcome. Moderation by pain might only exist at certain levels of physical activity. Our measures of physical activity were linear in nature, and we could not address potential effects of different intensity levels. Furthermore, we did not assess whether participants interpreted pain as a cause of physical activity (or age), which might be relevant for their interactive relation to subjective age. It is also conceivable that the relation between pain, physical activity and subjective age is more complex. For instance, pain might be predictive of both activity and subjective age, and when entered together in a model, results as the strongest predictor. Furthermore, pain could also function as a mediator in the relationship between. Physical activity and subjective age. Finally, different aspects of pain, such as whether it is chronic or acute, could all play a role in modulating its relationship with both physical activity and subjective age. In future studies, differentiated assessments of both pain and physical activity are warranted to better understand their interactive effect in people's subjective aging experiences.

Limitations and Directions for Future Research

The current study is original in its focus on the momentary objective and subjective experiences and conditions that impact subjective age as people go about their daily lives, and it adds to previous studies linking physical activity and subjective age in long-term studies and in the laboratory. Still, some limitations should be considered when interpreting our findings.

Our sample size was comparatively small, and variability in subjective age was not given for all participants, which limits our ability to detect small and more complex relations like moderation effects. Drawing from the literature of acute exercise and its relation to cognitive measures (Chang et al., 2012), effects seem to be generally rather small. Given that the initial models including movement acceleration revealed a trend of an effect of physical activity on momentary subjective age, future studies should revisit these associations with larger samples. Our sample was heterogeneous in terms of life situation and physical fitness, however, our study advertisement and wearing the sensor might have prompted people to be more active during the study than usual. Furthermore, the age range was rather narrow. It might be interesting to include a broader age range, especially adding participants in their late sixties and seventies, to see whether the relation of physical activity and the moderating effect of pain might be more pronounced in these groups, when activity might become more strenuous and pain experiences more frequent (Schmidt et al., 2024).

As our study included fixed assessment intervals, we did not have control over how other moments of physical activity could have related to participants' felt age. Future studies should consider measuring momentary subjective age in moments prompted by physical activity to detect higher intensities and more relevant occasions.

4.6 Conclusions

Our study highlights many underexplored aspects of subjective age in a sample of adults in late midlife. Physical activity seems to have smaller effects that future studies should consider when deciding on sample sizes and schemes. The experience of pain was robustly associated with higher momentary subjective age. Our study measured physical activity, pain, and subjective age in people's daily life, which might be highly informative for preventive interventions targeted at the adult population.

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Epilogue

Chapter 5 – Discussion of Main Findings

The following chapter aims at integrating the findings from Chapters 2-4 into an overall discussion. It will commence with a summary and recognition of the specific contribution of each of the chapters. The subsequent section will offer a broader discussion of how the specific findings of this thesis can fit into a larger discussion on temporal aspects of views of aging and their drivers. The final section offers recognition of the strengths and limitations of this thesis while also pointing toward recommendations and outlooks for future studies. I close this chapter and thesis with some concluding words.

5.1 Main Findings and Their Impact

The current thesis combines three distinct studies, each examining views of aging and potential predictors across different timelines, spanning months to moments. This was motivated by previous works pointing to fluctuating facets of views of aging (Bellingtier et al., 2017; Cohn-Schwartz & Gerstorf, 2022; Hughes & Touron, 2021; Kornadt et al., 2021; Weiss & Weiss, 2019), which introduced the idea of incorporating shorter time scales to extend knowledge from long-term longitudinal studies investigating views of aging and their determining factors. From these previous studies, several open questions remained about how different views of aging fluctuate across different timescales and which contextual factors might be related to views of aging through various pathways. Therefore, many potential drivers of such fluctuations remain unaccounted for, and this work builds on previous research by providing evidence for factors and contexts (cognition and emotions, physical

activity, health problems, perceived health, pain, and awareness of age-related gains and losses) that can influence views of aging dynamics.

Chapter 2 examined subjective age and its association with psychological factors in the broader context of the COVID-19 pandemic. Our findings indicated that in a highly age-salient era of the COVID-19 pandemic characterized by age stereotypes and ageism, people felt older over three months. Changes in people's subjective age were associated with COVID-19-related cognitions (in terms of risk perceptions) and emotions (in terms of worries). People who perceived a lower risk of becoming seriously ill if infected and whose health was good were likely to report younger subjective age. For people who worried more, having worse health was associated with a younger subjective age, but being in good health was associated with feeling older. In other words, the significance and direction of emotions and cognitions' effects on subjective age depended on people's health status. This underlines the importance of health and its interaction with cognitions and emotions in how people construe their subjective aging. Chapter 2 further demonstrates how views of aging and other factors are often associated via complex bidirectional relationships and underscores how directional conclusions are not straightforward to make.

Chapter 3 demonstrated fluctuations in views of aging across days, which aligns with previous studies (Armenta et al., 2018; Bellingtier & Neupert, 2019; Bellingtier et al., 2017). Daily variation in health problems was significantly associated with these fluctuations. In this study, we hypothesized that individuals' perceptions of their aging—whether positive or negative in terms of age-related gains and losses—would provide an internal context that moderated this association. As this study included three different operationalizations of views of aging (uni- and multidimensional subjective age and subjective accelerated aging), a nuanced picture emerged. Whereas health problems were significantly associated with the daily fluctuation of all views of aging measures, awareness of age-related gains and losses

only influenced this association for the multidimensional measure of subjective age and subjective accelerated aging. Chapter 3 underscores the multifaceted aspect of views of aging and how these facets may provide different insights into fluctuations and drivers of views of aging.

Chapter 4 brings novelty by being one of the first studies that examine the drivers of momentary fluctuations in views of aging. This study replicated findings of Kornadt et al. (2021) by demonstrating substantial momentary fluctuations in subjective age. It further shows how objective measures of momentary physical activity are associated with momentary changes in how old people feel. This study is original as it is the first to explore the additional role of pain for subjective age in a momentary timeframe. Although pain was hypothesized to represent an internal context that would moderate the association between physical activity and subjective age, it emerged as a strong independent predictor of subjective age.

This thesis extends the field by showing that examining views of aging from distinct timelines generates essential insights into the nature of adults' aging identities. These timelines are important because the drivers themselves have different temporal relevance, which is also accounted for in the design of each study. In short, this thesis includes hitherto underexplored drivers of views of aging (pain), novel objectively measured drivers of views of aging (physical activity), moderating factors (subjective health, awareness of age-related gains and losses), and bidirectional associations between views of aging and the respective psychological, physiological, and behavioral variables.

5.2 Integrative Discussion

The presented findings have several implications for theory and research regarding views of aging and their relation to development in later life. This relates primarily to the

different timeframes and short-term fluctuations in views of aging and the various pathways and mechanisms through which views of aging are influenced.

Fluctuating Views of Aging - What Did We Learn?

An overall goal of the thesis has been to illuminate how views of aging can fluctuate over distinct, short-term timeframes. Views of aging demonstrated significant fluctuations over months, as well as across and within days. In line with previous studies, Chapters 3-4 demonstrated that most of the variation in views of aging is related to between-person levels. Nevertheless, there is considerable variation at the within-person level. Chapters 3 and 4 demonstrate how these fluctuations are also substantial across very short timeframes. Intra-individual variation in subjective age measures accounted for 21-29% of the total variation, and subjective accelerated aging as much as 41%. This supports the idea that views of aging have state-like components (Hughes & Touron, 2021; Weiss & Weiss, 2019). A question here is whether these fluctuations are lasting and meaningful. Fluctuations in psychological factors may be considered a basis for adaptation and strength (Kashdan & Rottenberg, 2010), although being too sensitive in terms of bigger or more frequent fluctuations could indicate vulnerability (MacDonald & Stawski, 2014). Considering emotional states for comparison, one may feel sad for a short while but then bounce back into either an average- or a different emotional state demonstrating both flexibility and stability. When emotional reactions become too intense, or last too long, they become problematic as exemplified by many psychological disorders. The stable-flexible dynamics appears to also be true for within-person fluctuations in views of aging, especially the narrower the timeframe of the variation discovered. People do vary from day-to-day and moment-to-moment, as demonstrated both in this work and by others (Bellingtier et al., 2017; Kornadt et al., 2021). Views of aging overall are associated with lifestyle choices and self-care behavior (Montepare, 2020); understanding

how possible states of views of aging relate to such behaviors could be important information for creating future interventions.

Furthermore, part of the argumentation for why short-term fluctuations in views of aging are important is the premise that these fluctuations may somehow accumulate into the overall views of aging that people hold (Hughes & Touron, 2021). Combining different timelines may further allow us to understand momentary shifts (temporary) versus sustained, and accumulated effects. Relatedly, it has been suggested that the cost and benefits of the different views of aging facets may only become apparent when several timeframes and domains are considered (Kornadt et al., 2020). Therefore, studying short-term fluctuation in views of aging can hopefully lead to conclusions about what makes some people feel younger than others and how these differences result in better or worse aging outcomes.

Factors and Contexts Driving Short-Term Fluctuations in Views of Aging

A second aim of this thesis has been to explore the factors and contexts that may cause short-term fluctuations in views of aging, acknowledging the importance of the immediate context consistent with the contextual framework (Hughes & Touron, 2021). This work demonstrates that significant associations exist between state components of views of aging and personal and age-symbolic proximal events that are related to people's health, physical activity, and psychological factors.

Related to the concept that fluctuations of views of aging translate into its overall trait-like facet is the idea that the premise of accumulating effects also applies to its driving factors. Temporally, it may not only be in the specific day or moment that factors influence views of aging dynamics but also through their accumulating effect over time. Encountering an age-salient situation once, such as forgetting that you already told a story to your wife, is not likely to make you feel younger several months or years later. On the other hand,

continuous encounters over time are likely to lead to an adjustment in your views of aging. While not the primary focus of this work, Chapter 2 addresses this point as the temporal length between measures permits some accumulation effects, which showed that people felt older over the course of the study. Future studies should consider examining how accumulating age-salient encounters lead to more lasting changes in people's views of aging.

Related to what has been found on short- and long-term effects of age stereotypes (Kornadt et al., 2023), these different temporal effects can be in distinct directions. For example, and in line with the findings on age stereotypes, a single situation may lead to short-term fluctuations that make people feel younger due to distancing processes that protect them from negative age stereotypes and preserve their self-esteem. Yet, the studies of this thesis did not find a clear pattern speaking for the short-term distancing process seen for the short-term effects of age stereotypes. For example, in the study of Chapter 4, people felt older in moments of more pain. Chapters 2 and 3 further demonstrate that these mechanisms are not as simple, as the direction of effects can be highly dependent on interactions between factors. First, this demonstrates how findings from separate views of aging constructs do not generalize from one to another but bring their unique aspect to the aging experience. Second, this shows that there may be different mechanisms at play and that their combined effects are not yet disentangled. In sum, encountering several age-salient situations that increase one's awareness of growing older may, over time, lead to an adjustment and an older subjective age. The mechanisms of such short- and long-term fluctuations are complex and need further investigation. Any clear inference on accumulating effects cannot be made and will need further investigation. Future studies should consider longitudinal and repeated time-series designs to approach these temporal effects.

Considering the weathering hypothesis and the idea of distal reference points, it is possible that temporally more distant factors and events can affect the short-term associations

between views of aging and its drivers. An example is Bellingtier et al. (2017), who showed that major life-events stressors can influence short-term associations between views of aging and daily stress. Neither of the works in this thesis considered measures of previous life events. Incorporating proximal and distal events, as well as their interactions, into future studies can provide a better insight into what drives views of aging fluctuations. A recent study has indeed found an association in both directions between pain and subjective age, on both within- and between-person levels (Wettstein et al., 2024): Those with more pain felt older compared to those with less pain, and on moments with more pain, people felt older compared to moments with less pain. Those with overall stronger pain experiences exhibited steeper increases in their subjective age. This further demonstrated how we must consider different facets of views of aging drivers when trying to understand their influence across timeframes.

A compelling new perspective on short-term fluctuations can be obtained through the experiential diversity theory of aging that has been proposed by Koffer et al. (2024). This theory stipulates that it is not only the immediate situations that play a role in how people age but also the diversity of experiences encountered. Experiential diversity declines with age (Koffer et al., 2024), and such changes may influence its impact on views of aging across chronological age. An interesting hypothesis would be that encountering a broader range of hourly/daily/weekly experiences that hold aging-relevant qualities may promote a better aging experience. In light of daily- and momentary assessment studies, this idea offers some interesting questions to be explored in future works. How important is the quantity of experiences for better views of aging? How does the quality of those experiences play a role in their influence, and lastly, are there interaction effects between positive and negative experiences?

Pathways for Factors Informing Views of Aging

In the introductory Chapter 1, I have demonstrated how the pathways suggested in the stereotype embodiment theory may also apply to factors influencing people's views of aging. Chapter 2 exemplifies how a psychological pathway may be possible as emotions and cognitions were related to fluctuations in people's views of aging over several months during the COVID-19 pandemic. This association was moderated by people's health, speaking for a possible interconnection between the different pathways. Chapter 3 supports this notion of interconnecting pathways informing views of aging. First, it supports a physiological pathway as health problems were associated with fluctuations in subjective age and subjective accelerated aging. Second, his relationship was further moderated by people's awareness of age-related changes, speaking for an interaction between physical and psychological pathways informing views of aging. Finally, such pathways can also operate momentarily, as Chapter 4 demonstrates that a behavioral pathway, represented by movement acceleration, is associated with momentary subjective age. The finding that pain, which may be contingent on a physiological path, was a major influence of subjective age, leaving physical activity non-significant, suggests that these pathways may not only be interconnected but could potentially also override one another. Moving forward, we should design future studies specifically targeting what mechanisms are underlying influences of other variables on views of aging constructs. Given the fact that direct effects have been difficult to establish overall for drivers of views of aging, it would be especially interesting to investigate further potential mediating paths that drive views of aging fluctuations.

In conclusion, pathways proposed in the stereotype embodiment theory may not only be relevant regarding the impact of aging stereotypes on development. The findings of the current thesis stress that one could also apply this framework to systematize influences on views of aging. It is further likely that factors influencing these constructs may operate

through similar pathways and mechanisms. As demonstrated, results from Chapters 2-4 provide an indication that this is indeed possible and that such pathways are interconnected as demonstrated in Figure 5.1.

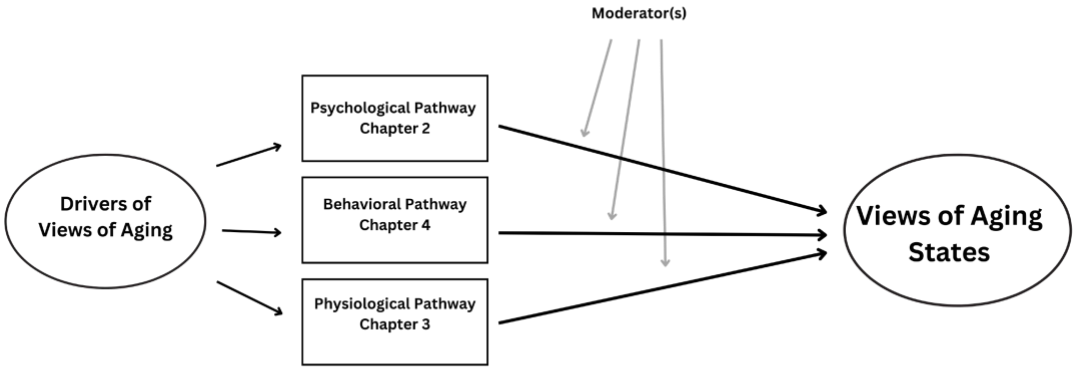

Figure 5.1. Visualization of the suggested pathway for driving factors of state components of views of aging. The chapters of this thesis have been placed under the path that they reflect best.

Objective measures

A strength of this thesis has been the inclusion of objectively measured drivers of views of aging fluctuations. Previously, such associations have mostly been found in experimental works (Stephan et al., 2013; Stephan et al., 2015a) and studies looking into biomarkers and aging (Kornadt et al., 2022). This thesis provides a first step in showing how such objective measures can relate to subjective aging experiences in daily life. Chapter 4 has demonstrated that objective measures of physical activity can be associated with subjective age fluctuations. Future studies should consider including such objective measures when exploring views of aging in daily life settings. This will allow us to build on the current

knowledge on how subjective- and objective processes affect views of aging, whether they offer similar or distinct associations with views of aging.

Multidimensionality of Views of Aging and Actual Measures

The way in which subjective age is assessed matters for how it relates to other factors and development, as demonstrated in the thesis introduction. In this work, Chapters 2 and 4 specifically studied subjective age by using the traditional one-item measure. The strengths of this measure are that it allows for efficient and comprehensible assessment of people's views of aging and facilitates comparison to the rich body of studies that have used this measure. Nonetheless, views of aging are considered multidimensional, and the literature recommends accounting for this in future studies (Hughes & Touron, 2021). Chapter 3 has, consequently, included three separate measures of views of aging, which further demonstrated that the choice of measure matters in the conclusions we can draw. Multidimensional subjective age and subjective accelerated aging showed more associations with the other study variables than the unidimensional subjective age measure. The multidimensionality of subjective age seems to be at least equally important in shorter timeframes as it is in longer timeframes.

5.3 Strengths, Limitations and Related Avenues for Future Research

The current work holds both assets and impediments. Overall, this thesis offers a novel look at views of aging that combine shorter longitudinal measures, where the momentary assessment of views of aging provides a special novelty. It further looks at new factors and their interactions associated with fluctuations in views of aging that have not previously been studied, for example, the association between pain and subjective age on a momentary level. In the next section, I look further into some shortcomings of this thesis

related to sample, design, analysis, and directional and causal inferences. These nuances should be considered when interpreting the findings, as well as how they add to the existing literature and how they can inform future studies.

A mantra in the views of the aging field is that views of aging must be understood from a developmental perspective. This thesis has provided insights into how factors are drivers of short-term fluctuations in views of aging, and above, I have discussed how these relate to theories of development. Still, the studies of Chapters 2-4 do not address the lifespan perspective directly. The studies cover relatively narrow age ranges in the second half of life (Chapter 1: 60-98 years, Chapter 3: 52-75 years, and Chapter 4: 50-62 years). When expanding the current literature, including a broader age range, would provide valuable insights into how the association between views of aging and its driving factors may differ across life stages, including young people.

Related to the drivers of views of aging, I have focused on situational and internal drivers that fluctuate on the same timescale as the fluctuations of views of aging. Naturally, there is a broad range of possible further drivers of views of aging fluctuations. As argued by both (Hughes & Touron, 2021; Neupert & Bellingtier, 2018), the broader contexts of macro-systems and lifespan experiences are expected to influence people's views of aging, often in interaction with the immediate context.

The design of the studies in Chapters 2-4 combines short longitudinal and micro-longitudinal designs. While these are great for informing us about short-term and within-person variations across their timelines, they do not reveal how these fluctuations change over time and the drivers of such long-term changes. Designing studies that employ repeated measures over short time scales and integrate them into a longitudinal design may reveal how short-term fluctuations change over time, which drivers are relevant at specific time points,

and how state components translate into people's overall aging entity (Ram & Gerstorf, 2009).

Relatedly, studies using repeated measures, such as in Chapters 3 and 4, may themselves function as interventions (Cohn-Schwartz & Gerstorf, 2022; Neupert & Bellingtier, 2018). For example, asking people frequently about their views of aging may increase their awareness of aging and prime them towards interpreting changes as being caused by their aging. One should keep this in mind when interpreting the results presented in this thesis. Nevertheless, this offers some interesting opportunities for future intervention studies that may be able to use this to their advantage. For example, creating two sets of repeated measures designs—one focusing on aging and the other not—could lead to an ecological study that compares groups of older individuals while uncovering the drivers and mechanisms behind their views of aging.

Finally, I would like to address the matter of directionality and causality. This thesis provides findings that relate state components of views of aging to their possible drivers. First, these associations may be bidirectional, and only Chapter 2 addresses this in the analysis. Further investigation of their directional interplay can provide further insights into the mechanisms at play. Second, I want to briefly make a note of the moderation effects investigated in this thesis. Chapters 2-4 demonstrate how the interactions between drivers of views of aging are not simple. This is especially highlighted in Chapter 2, where the association between worries and subjective age was only significant with health as a moderator. This could also speak for the possibility of health having the function of a mediator in this context. Third, the results from the studies of this thesis do not allow us to draw conclusions on the causality of these associations. Chapter 4 taps into this by measuring physical activity temporally prior to measuring subjective age, and Chapter 2 with its longitudinal design. We will need a broader body of studies to arrive at causal interpretations.

Not only do we need to study short-term fluctuations over time, but we also need to consider comparing naturally occurring group differences, matching individuals, or, as previously mentioned, conducting ecological assessment intervention studies.

5.4 Conclusion

To conclude, this thesis supports the notion that there are meaningful, short-term fluctuations in views of aging dynamics. This builds on the growing literature that has taken an interest in how short-term dynamics can provide important information about people's views of aging. These findings are relevant for future research as it shows that the timeframe matters and should consequently be chosen with care.

Furthermore, drivers related to behavioral, psychological, and physical domains have been identified as worries, risk perceptions, health, and pain have been associated with views of aging fluctuations over shorter timeframes. I have further demonstrated that momentary- and objectively measured factors offer great potential for insights into views of aging dynamics. Moderation contexts have been explored and found, speaking for the expected complexity of how people construe their views of aging. I have discussed how these may be seen in light of theory such as the pathways suggested in the stereotype embodiment theory.

Acknowledging that our knowledge on views of aging dynamics is still sparse, I have suggested several avenues for future research to investigate these dynamics based on this thesis, which include exploring cumulative effects of driving factors, distant influences that may affect short-term variations in views on aging, and the range of daily life experiences encountered in specific timeframes.

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Appendices

Appendix Chapter 2

Table A2.1
Results from the cross-lagged model with subjective age, worry, subjective health as a moderator and all covariates. The conceptual model is presented in Fig 1.

T1 Correlations						
T1 correlations SA1						
Worry1		.111				.009
Age		-.116				.006
Edu		.036				.427
Gender	.014				.738	
SH		-.290				<.00
T1 correlations Worry1						
Age		-.054				.180
Edu		-.068				.109
Gender	-.004				.930	
SH		-.178				<.001

Cross-lagged results		*β*		SE *β*		*p*
Dependent variable: SA2						
SA1		.618		.032		<.000
Worry1		.018		.037		.624
Age		.005		.038		.896
Edu		.054		.040		.179
Gender	-.051		.036		.150	
SH		-.086		.041		.036
Worry1*SH		.137		.040		.001
Dependent variable: Worry2						
Worry1		.512		.034		<.001
SA1		.071		.044		.107
Age		-.012		.039		.758
Edu		.057		.044		.193
Gender	-.026		.038		.499	
SH		-.058		.044		.180
SA1*SH		.034		.051		.507

Residual correlation						
SA2 with Worry 2		.030				.521

Note. β = standardized regression coefficient, SE β = standard error β, p = significance level. SA1, subjective age timepoint 1; SA2, subjective age timepoint 2; Worry1, worry of falling ill with Covid-19 timepoint 1; Worry2, worry of falling ill with Covid-19 timepoint 2; SH, subjective health timepoint 1; Age, chronological age timepoint 1; Edu, education timepoint 1; Gender, participant gender timepoint 1. All control variables at T1 were also correlated with one another.

Table A2.2

Results from the cross-lagged model with subjective age, perceived risk of infection and subjective health as a moderator and all covariates. The conceptual model is presented in Fig 1.

T1 Correlations	*r*	*p*
T1 correlations SA1		
Prisk1	-.012	.794
Age	-.115	.006
Edu	.037	.404
Gender	.010	.810
SH	-.286	<.001
T1 correlations Risk1		
Age	-.042	.312
Edu	-.020	.649
Gender	.048	.250
SH	-.073	.082

Cross-lagged results	β	SE β	*p*
Dependent variable: SA2			
SA1	.604	.040	<.000
Prisk1	-.005	.038	.895
Age	.007	.038	.854
Edu	.053	.040	.192
Gender		.188	
SH	-.079	.041	.051
Prisk1*SH	.062	.043	.149
Dependent variable: Prisk2			
Prisk1	.489	.040	<.001
SA1	.000	.048	.993
Age	.007	.041	.869
Edu	.037	.046	.416
Gender	-.006	.041	.880
SH	-.013	.046	.780
SA1*SH	.021	.053	.695

Residual correlation		
SA2 with Prisk2	.154	.001

Note. β = standardized regression coefficient, SE β = standard error β, p = significance level. SA1, subjective age timepoint 1; SA2, subjective age timepoint 2; Prisk1, perceived risk of contracting the Covid-19 timepoint 1; Prisk2, perceived risk of contracting Covid-19 timepoint 2; SH, subjective health timepoint 1; Age, chronological age timepoint 1; Edu, education timepoint 1; Gender, participant gender timepoint 1. All Control variables at T1 were also correlated with one another.

Table A2.3

Results from the cross-lagged model with subjective age, perceived risk of serious course of disease, subjective health as a moderator and all covariates. The conceptual model is presented in Fig 1.

T1 Correlations		
T1 correlations SA1		
Prisk1	-.147	.001
Age	-.115	.006
Edu	.034	.445
Gender	.012	.785
SH	-.287	<.001
T1 correlations RiskS1		
Age	-.150	<.000
Edu	-.065	.142
Gender	-.046	.277
SH	-.368	<.001

Cross-lagged results	β	SE β	p
Dependent variable: SA2			
SA1	.611	.032	<.000
PriskS1	.091	.041	.028
Age	-.014	.038	.712
Edu	.053	.040	.189
Gender	-.045	.036	.211
SH	-.067	.043	.119
PriskS1*SH	.136	.044	.002
Dependent variable: PriskS2			
PriskS1	.533	.037	<.001

SA1		.021		.044		.640
Age		.067		.040		.089
Edu		-.034		.042		.418
Gender	.002		.038		.950	
SH		-.013		.046		.780
SA1*SH		.021		.053		.695
Residual correlation						
SA2 with PriskS2		.107				.031

Note. β = standardized regression coefficient, SE β = standard error β, p = significance level. SA1, Subjective age timepoint 1; SA2, subjective age timepoint 2; PriskS1, perceived risk of contracting the Covid-19 timepoint 1; PriskS2, perceived risk of contracting Covid-19 timepoint 2; SH, subjective health timepoint 1; Age, chronological age timepoint 1; Edu, education timepoint 1; Gender, participant gender timepoint 1.

Appendix Chapter 4

Table A4.3

Multilevel Regression Analyses Predicting Momentary Subjective Age from Movement Acceleration (20-minute interval), Pain, Interaction Term and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Moac20	**-.81 (.36)**	.022	-.63 (.36)	.076	-.63 (.36)	.078	-.63 (.36)	.076	.44 (2.31)	.848	.52 (2.27)	.819
Pain			**4.62 (1.03)**	<.001	**4.63 (1.03)**	<.001	**4.62 (1.03)**	.000	**5.52 (2.32)**	.017	**5.58 (2.29)**	.015
Moderation					- 1.54 (3.91)	.694			-2.01 (4.13)	.627	-2.14 (4.05)	.597
Between												
Moac20							-.50 (9.47)	.958	12.66 (15.77)	.422	26.83 (22.81)	.240
Pain							**14.82 (3.84)**	.000	**24.94 (9.72)**	.010	28.02 (15.92)	.078
Moderation									-23.05 (19.27)	.232	-36.52 (33.33)	.273
BMI											3.64 (2.32)	.117
MET											**-5.27 (1.92)**	.006
Age											**-.31 (.13)**	.020
$R2_{within}$	.004	.235	.053	.002	.054	.002	.054	.002	.083	.414	.860	.409
$R2_{between}$							.319	.001	.637	.003	.819	<.001

Note
. b = unstandardized regression coefficient. SE = standard error. Values significant at p <.05 are in bold. Model 1: within-level only with movement acceleration. Model 2: within-level only with movement acceleration and pain. Model 3: within-level only with movement acceleration, pain and moderation. Model 4: two-level model with movement acceleration and pain. Model 5: two-level model with movement acceleration, pain and moderation. Model 6: two-level model with movement acceleration, pain, moderation, and covariates.

Table A4.4

Multilevel Regression Analyses Predicting Momentary Subjective Age from Movement Acceleration (30-minutes interval), Pain, Interaction Term and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Moac30	**-.80 (.33)**	.017	-.58 (.31)	.065	-.59 (.32)	.067	-.60 (.32)	.064	.92 (2.15)	.670	1.01 (2.09)	.629
Pain			**3.84 (.95)**	<.001	**4.63 (1.03)**	<.001	**4.61 (1.03)**	<.001	**5.88 (2.18)**	.007	**5.974(2.13)**	.005
Moderation					- 1.55 (4.25)	.714			-2.79 (3.83)	.466	-2.95 (3.71)	.427
Between												
Moac30							3.58 (10.75)	.739	20.87 (24.22)	.389	39.30 (36.79)	.285
Pain							**15.23 (3.91)**	<.001	28.73 (15.77)	.068	35.00 (26.69)	.190
Moderation									-30.88 (32.11)	.336	-51.09 (63.70)	.357
BMI											3.43 (2.17)	.115
MET											**- 591 (2.05)**	.004

Age											**-.30 (.13)**	.022
$R2_{within}$	.004	.216	.012	.027	.053	.003	.054	.003	.104	.379	.110	.361
$R2_{between}$							.333	.001	.728	.012	.910	<.001

Note. b = unstandardized regression coefficient. SE = standard error. Values significant at p <.05 are in bold. Model 1: within-level only with movement acceleration. Model 2: within-level only with movement acceleration and pain. Model 3: within-level only with movement acceleration, pain, and moderation. Model 4: two-level model with movement acceleration and pain. Model 5: two-level model with movement acceleration, pain, and moderation. Model 6: two-level model with movement acceleration, pain, moderation, and covariates.

Table A4.6

Multilevel Regression Analysis Predicting Momentary Subjective age with Step Count (20-minutes interval), Pain, the Interaction Term, and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Steps20	-.14 (.13)	.276	-.10 (.13)	.462	-.10 (.13)	.463	.10 (.13)	.465	.45 (.85)	.597	.46 (.84)	.580
Pain			**4.65 (1.03)**	<.001	**4.66 (1.03)**	<.001	**4.65 (1.03)**	<.001	**6.30 (2.90)**	.030	**6.34 (2.87)**	.027
Moderation					.10 (1.53)	.950			-1.05 (1.56)	.501	-1.08 (1.54)	.485
Between												
Steps20							2.41 (6.51)	.711	5.94 (7.41)	.422	12.09 (8.12)	.136
Pain							**15.04 (3.75)**	<.001	**23.73 (7.36)**	<.001	**26.12 (12.29)**	.034
Moderation									-5.25 (3.90)	.178	-8.74 (7.19)	.224
BMI											4.12(2.52)	.102
MET											**-5.35 (2.00)**	.007
Age											**-.29 (.13)**	.025
$R2_{within}$	.000	.706	.051	.006	.051	.006	.053	.006	.062	.157	.117	.403
$R2_{between}$							.362	.001	.915	.106	.784	<.001

Note. b = unstandardized regression coefficient. SE = standard error. Values significal at p <.05 are in bold. Model 1: within-level only with step count. Model 2: within-level only with step count and pain. Model 3: within-level only with step count, pain and moderation. Model 4: two-level model with step count and pain. Model 5: two-level model with stepcount, pain and moderation Model 6: two-level model with step count, pain, moderation and covariates.

Table A3.7

Multilevel Regression Analysis Predicting Momentary Subjective age with Step Count (30-minutes interval), Pain, the Interaction Term and Covariates.

Variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*	b(SE)	*p*
Within												
Steps30	-.09 (.12)	.450	-.03 (.12)	.819	-.03 (.12)	.811	-.03 (.12)	.805	.08 (.41)	.842	.11 (.41)	.778
Pain			**4.66 (1.03)**	<.001	**4.66 (1.03)**	<.001	**4.66 (1.03)**	<.001	**5.03 (1.69)**	.003	**5.14 (1.70)**	.002
Moderation					.34 (1.43)	.811			-.21 (.78)	.787	-.27 (.78)	.730
Between												
Steps30							5.86 (7.02)	.404	17.06 (36.81)	.643	**25.12 (12.20)**	.039
Pain							**15.49 (3.81)**	<.001	47.12 (104.73)	.653	60.52 (32.75)	.065
Moderation									-16.35 (53.33)	.759	- 24.95 (16.71)	.135
BMI											2.55 (1.92)	.185
MET											**- 6.41 (2.00)**	.002
Age											**- .34 (.12)**	.004
$R2_{within}$	.000	.706	.051	.006	.051	.006	.053	.006	.062	.157	.065	.162
$R2_{between}$							.362	.001	.915	.106	.992	<.001

Note. b = unstandardized regression coefficient. SE = standard error. Values significal at p <.05 are in bold. Model 1: within-level only with step count. Model 2: within-level only with step count and pain. Model 3: within-level only with step count, pain and moderation. Model 4: two-level model with step count and pain. Model 5: two-level model with stepcount, pain and moderation Model 6: two-level model with step count, pain, moderation and covariates.