On Retirement and Cognitive Aging from a Life-Span Perspective

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Doctoral Dissertation in Psychology
Department of Psychology
University of Gothenburg
December 17, 2021

Cover picture: Magnus Hedman
Printing: STEMA SPECIALTRYCK AB
Gothenburg, Sweden, 2021
ISBN (Print): 978-91-8009-566-2
ISBN (PDF): 978-91-8009-567-9
ISSN 1101-718X Avhandling/Göteborgs universitet, Psykologiska institutionen

Abstract

Zulka, L. E. (2021). *On Retirement and Cognitive Aging from a Life-Span Perspective.* Department of Psychology, University of Gothenburg, Sweden.

Retirement is a major life event potentially affecting domains such as cognitive functioning and well-being. The main aim of this thesis was to assess whether retirement influences cognitive functioning and how inter- and intra-individual differences in psychological and lifestyle factors moderate the association. A secondary purpose was to evaluate whether general intelligence, as measured at age 18, and social contacts later in life may function as resources for successful adaptation to retirement from work. In **Study I**, we systematically reviewed current literature to evaluate patterns of findings regarding the impact of retirement on cognition. Peer-reviewed studies (*n* = 20) with longitudinal designs were reviewed. The studies reported negative, positive, and no effect of retirement on cognitive function. These conflicting results were explained neither by variations in study characteristics nor by the use of different measures of cognitive abilities. We found a positive trend for cognitive functioning for retirement from physically demanding jobs. For retirement from cognitively demanding jobs, the evidence was conflicting. **Studies II, III** and **IV** were based on data from the HEalth, Aging and Retirement in Sweden (HEARTS) study (*n* = 5913). In **Study II** (*n* = 631), we examined whether retirement influenced cognitive functioning, and modeled the interaction between job demands before retirement, changes in leisure activities over the retirement transition, and their relationship to post-retirement cognitive functioning. Results indicated that retirement did not generally led to poorer cognitive development. Furthermore, increased cognitive stimulation, through cognitively demanding leisure activities, had beneficial effects on post-retirement memory development among individuals who reported low previous cognitive work demands. In **Study III** (*n* = 3851), we investigated the relationship between the Big Five personality traits and the level of and change in reasoning ability in the years around retirement. Higher levels of extraversion, conscientiousness, and neuroticism were related to lower levels of reasoning ability, whereas higher levels of openness were associated with higher levels of reasoning ability. We found no association between any of the Big Five personality traits and the rate of change in reasoning ability in the years around retirement. In **Study IV**, we merged HEARTS data with IQ measures derived from military conscription (*n* = 924). We found that IQ in young adulthood was unrelated to levels of life satisfaction before retirement. However, increases in contact with friends were associated with increases in life satisfaction and this increase was strongest for individuals with lower IQ scores. To conclude, our findings provide evidence that retirement does not generally negatively affect cognitive functioning, at least from a short-term perspective. Cognitive functioning in the years around retirement relates to different possibly modifiable psychological and lifestyle factors that potentially stimulate positive cognitive developments.

Keywords: cognitive aging, retirement transition, leisure activity engagement, work demands, personality, life satisfaction, initial IQ, social contacts

Swedish Summary

Arbetskraften åldras snabbt som en följd av demografiska förändringar, som t.ex. att den så kallade babyboomer-generationen blir äldre och att den förväntade livslängden ökar. Dessa trender leder till att medelåldern ökar liksom proportionen mellan de delar av samhället som inte utgör arbetskraften och de som utgör arbetskraften, vilket också kallas ett åldrande samhälle. Följaktligen kommer fler människor än någonsin att gå i pension under de kommande åren och de flesta människor kommer att tillbringa en större del av sin livstid i pension än någon annan generation tidigare.

Pensioneringen är därmed en viktig livshändelse för många som även kan påverka områden som kognitiv funktion och välbefinnande. Övergången från arbete till pension sker vanligtvis i samma ålder som de första åldersrelaterade kognitiva försämringarna förekommer. En god kognitiv funktion i ålderdomen är avgörande för äldre vuxnas livskvalitet. Att förstå kritiska perioder för kognitiv funktion senare i livet är därför av stor vikt. För att möta de nuvarande demografiska utmaningarna och samtidigt främja (kognitiv) hälsa är det avgörande att först förstå den eventuella påverkan som pensionering har på kognitiv funktion. Dessutom kan kognitiv funktionsförmåga – som till stor del bestäms tidigt i livet – också påverka anpassningen till pensionering och välbefinnandet efter pensioneringen. Även om forskning om dessa frågor har ökat under de senaste åren är relationen mellan pensionering och kognition fortfarande inte helt klarlagd.

Huvudsyftet med denna avhandling var därför att undersöka om pensionering påverkar kognitiv funktion och hur inter- och intraindividuella skillnader i psykologiska faktorer och livsstilsfaktorer hänger ihop med detta. Ett sekundärt syfte var att utvärdera om allmän intelligens, mätt vid 18 års ålder, och sociala kontakter senare i livet kan fungera som resurser för en framgångsrik anpassning till pensionering från arbetet. Avhandlingen består av fyra empiriska studier och **studier II, III** och **IV** baserades på den svenska studien HEARTS (HEalth, Aging and Retirement Transitions in Sweden) som inleddes år 2015. HEARTS (*N* = 5913) följer enskilda individer under loppet av deras pensionsövergång och omfattar en mängd sociodemografisk, arbets- och pensionsrelaterad information samt psykologiska och kognitiva hälsodata som samlas in i en longitudinell design.

I de fyra studierna undersökte vi kognitivt åldrande i förhållande till pensionering medan vi tillämpade ett livsloppsperspektiv. Denna teoretiska ram utgår ifrån att mänsklig utveckling är en livslång process som innebär beteendeförändringar under hela livsloppet. Den övergripande idén är att biologiska processer och genetiska förutsättningar i viss mån bestämmer människans utveckling, medan sociala och miljömässiga faktorer samt individuella erfarenheter och deras interaktion med varandra formar den fortsatta utvecklingen. Konceptet om livstidsutveckling i förhållande till kognitiv utveckling ger därför en bra bas för att beskriva och eventuellt förklara intra- och interindividuella skillnader i kognitiva förändringar under livsloppet.

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I **studie I** gick vi systematiskt igenom den aktuella vetenskapliga litteraturen för att utvärdera resultat om pensioneringens inverkan på kognition. En systematisk litteratursökning resulterade i 20 longitudinella studier. Resultaten visade på negativa, noll- och positiva samband mellan pensionering och kognition. De motstridiga resultaten kunde inte förklaras av variationer i studiernas egenskaper (studiens kvalitet, operationalisering av pensionering, analytiskt tillvägagångssätt) eller kognitiva förmågor. I studier där yrkeserfarenheter ingick som en moderator fanns det dock en positiv trend för kognitiv funktion när man gick i pension från fysiskt krävande arbeten. Vi drog slutsatsen att för att få en inblick i mekanismerna bakom förhållandet mellan pensionering och kognitiv funktion måste studiedesignerna ta hänsyn till effekterna av faktorer före pensioneringen och i själva pensioneringsövergången.

I **studie II** följde vi upp resultaten från **studie I**. Vi var särskilt intresserade av samspelet mellan att gå i pension från arbeten med varierande yrkeskrav och engagemang i kognitivt stimulerande fritidsaktiviteter. I litteraturgenomgången fann vi positiva effekter av pensionering för pensionärer som lämnade fysiskt krävande arbeten och både positiva och negativa effekter för de som lämnade kognitivt krävande arbeten och tjänstemannajobb. De positiva effekterna av pensionering på kognitiv funktion hos de som lämnade fysiskt eller kognitivt krävande arbeten antogs främst bero på att ett ökat engagemang i kognitivt stimulerande fritidsaktiviteter efter pensioneringen ökar den kognitiva funktionen. Dessutom kan förlusten av daglig kognitiv stimulans efter pensioneringen öka betydelsen av att ägna sig åt kognitivt stimulerande fritidsaktiviteter. Vi undersökte därför om pensioneringen påverkade den kognitiva funktionen och modellerade samspelet mellan arbetskrav före pensioneringen, förändringar i fritidsaktiviteter under pensioneringen och deras relation till den kognitiva funktionen efter pensioneringen. Vi använde data ($N = 631$) från fem vågor av upprepade årliga mätningar från HEARTS studien och modellerade minnesförändringar med hjälp av piecewise tillväxtkurvmodeller. Resultaten visade att ökad kognitiv stimulans från fritidsaktiviteter hade positiva effekter på minnesutvecklingen efter pensioneringen bland individer som rapporterade tidigare låga kognitiva arbetskrav. Våra resultat gav delvis stöd för att pensionärer från mindre kognitivt krävande yrken kommer att vinna på att öka engagemang i kognitiva fritidsaktiviteter efter pensioneringen.

I **studie III** undersökte vi sambandet mellan personlighet (Big Five personlighetsdrag) och nivå och förändring av resonemangsförmåga under åren kring pensioneringen (N = 3851). Personlighet kan vara av särskilt intresse för kognitiv funktion under åren runt pensioneringen, eftersom särskilda personlighetsdrag kan tänkas bidra till att underlätta eller försvåra anpassningen till pensioneringen från arbetet, vilket i sin tur kan ha betydelse för kognitiv funktion (dvs. förmåga att resonera). Resultaten från en strukturell ekvationsmodell med kontroll för ålder, utbildning och kön, visade att högre nivåer av extraversion, samvetsgrannhet och neuroticism var förknippade med lägre resonemangsförmåga. Högre nivåer av öppenhet var förknippat med bättre resonemangsförmåga. Nivån på tillmötesgående var inte relaterad till nivån av resonemangsförmåga. Vi fann inget samband mellan något av Big Five personlighetsdragen och förändringar i resonemangsförmåga under åren kring pensioneringen. Våra resultat replikerade tidigare fynd som visar att personlighetsdrag är förknippade med individskillnader i kognition bland äldre vuxna.

Särskilt i samband med pensioneringen kan en god kognitiv funktion fungera som en resurs för personer som behöver hantera förändringar i sina liv. Mer kognitiva resurser kan följaktligen vara en faktor som främjar högre välbefinnande när man går i pension. Att ha en högre IQ redan tidigt i livet kan bidra till att man lära sig en rad olika copingstrategier under sin livstid som kan användas för eventuella utmaningar i samband med åldrandet. Det är också möjligt att en högre IQ tidigt i livet ökar chanserna att göra karriär med arbets- och pensionsvillkor (t.ex. större ekonomisk trygghet) som främjar livstillfredsställelse senare i livet. Även sociala relationer främjar livstillfredsställelse och högre välbefinnande i pensioneringen och kan därför också ses som resurser för en framgångsrik anpassning till pensionering. Det är dock oklart hur dessa resurser samverkar. Syftet med **studie IV** var att undersöka sambandet mellan IQ, mätt vid 18 års ålder, och sociala kontakter senare i livet med livstillfredsställelse under pensioneringen. Vi använde data från sex vågor av upprepade årliga mätningar från HEARTS och IQ-data från den militära värnplikten (N = 924 män). Resultat från strukturella ekvationsmodeller visade att IQ i ung vuxen ålder inte var förknippat med nivåer av livstillfredsställelse innan pensioneringen. Ökad livstillfredsställelse hängde samman med ökad kontakt med vänner. Största ökningen av livstillfredsställelse hittades hos individer med lägre IQ och mer ökning av kontakter med vänner.

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Sammanfattningsvis ger våra resultat belägg för att pensionering inte generellt sett påverkar kognitiva funktioner negativt, åtminstone i ett kortsiktigt perspektiv. Dessutom verkar kognitiv funktion under åren runt pensioneringen vara förknippat med olika psykologiska faktorer och livsstilsfaktorer (dvs. yrkeskrav, fritidsaktiviteter, personlighet) som eventuellt kan ändras och som kan främja en positiv kognitiv utveckling.

Våra resultat visar också att faktorer i tidig vuxen ålder verkar interagera med faktorer senare i livet. För att bättre förstå anpassningen till pensioneringen kan det alltså vara lärorikt att beakta faktorer som inverkar på utvecklingen under hela livet och som påverkar tillgången till resurser senare i livet.

Preface

This thesis consists of a summary and the following four papers, which are referred to by their roman numerals:

I Zulka, L. E., Hansson, I., & Hassing, L. B. (2019). Impact of retirement on cognitive function: A literature review. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry, 32*(4), 187-203.

II Zulka, L. E., Thorvaldsson, V., Hansson, I., & Hassing, L. B. (2021). Effects of work demand and changes in leisure activity on post-retirement memory. *GeroPsych: The Journal of Gerontopsychology and Geriatric Psychiatry.* Advance online publication.

III Zulka, L. E., Hansson, I., Hassing, L. B., & Thorvaldsson, V. (2021). Personality and reasoning ability during retirement age: Report from a Swedish population-based longitudinal study. *Journal of Research in Personality.* Advance online publication.

IV Zulka, L.E., Thorvaldsson, V., Hansson, I., & Hassing, L.B. (2021). *The role of young adulthood intelligence and contact with friends in life satisfaction during the retirement transition.* Manuscript submitted for publication.

Contents

Figures and Tables

Acknowledgements

This work would not have been possible without the support of many great people and I am grateful to everyone who contributed to this thesis and my time as a PhD student.

For the opportunity to work at the Department of Psychology, your knowledge- and expertise-sharing, optimistic encouragement and guidance, I want to sincerely thank my supervisor team *Linda B. Hassing* and *Valgeir Thorvaldsson*. Thank you both for helping me keeping track, calming me down when needed, and for your uplifting Icelandic humor in stressful times.
Many thanks to *Ann Frisén* for being an encouraging examiner. I would also like to thank Associate Professor *Michael Rönnlund* for your valuable comments on this thesis and Professor *Nancy Pedersen* for acting as my opponent.

Thanks to all members of my research group, the LIFE Lab, *Martin Lövdén, Magnus Lindwall*, *Anne Ingeborg Berg, Sandra Buratti, Sindre Engelbrekt Rolstad,* and *Amos Pagin* for welcoming me so warmly, all interesting discussions, and the positive work atmosphere. *Boo Johansson* and *Marie Kivi*, thank you for always keeping the big picture and the smallest details of the HEARTS study in mind. A special thanks to *Stefanie König, Isabelle Hansson, Georg Henning, Pär Bjälkebring,* and *Johan Skoog* for all your support and the fun times we have. Thank you to all HEARTS participants who make our research possible.

I would also like to thank the organizers and my fellow PhD colleagues at the National Graduate School on Ageing and Health (SWEAH), Lund University for creating a space for learning and interdisciplinary exchange.

Thank you to all my friends and colleagues at the department who have made me feel so welcome at this new university and in a new country, especially to my årskull *Emma Ejelöv*, *Malin Joleby*, and *Patrik Michaelsen*. *Érika Ramos* and *Hanna Larsson*, thank you for being the best roommates and the good times we share! Thank you to all my PhD colleagues and friends, *Maria Gröndal, Sofia Calderon, Lina Nyström, Andrea Karlsson Valik, Gustaf Glavå, Isac Sehlstedt, Lina Wirehag Nordh, Py Eriksson, Karl Ask, Erik Mac Giolla,* and *Jonas Burén* for keeping the good spirit even in these weird pandemic times. Big thanks to *Timothy Luke* for all interesting (R-)discussions. Thank you to *Ann Backlund* for all the support during my time as a PhD student.

A huge thanks goes to my dear friends in Germany and Sweden who make life easy and great. My family and especially my parents, you could not be more supportive and loving, thanks for always being there for me and for encouraging all my decisions. *Basti*, thank you for your infinite support and for being at my side no matter what.

I would also like to express my thankfulness for the financial support of this thesis to the Swedish Research Council for Health, Working Life and Welfare (HEARTS Dnr 2013-2291; AGECAP Dnr 2013-2300), Donationsnämndens stipendier at the University of Gothenburg, and Adlerbertska Forskningsstiftelsen.

INTRODUCTION

The labor force is aging rapidly as a consequence of demographic changes such as the aging of the baby-boomer generation and increasing life expectancy. These trends lead to increases in average age as well as in the ratio between parts of society not in the labor force and those in the labor force (i.e., age dependency ratio), indicating the emergence of what is referred to as an aging society. Consequently, more people than ever will retire from work in the coming years and most people will spend a greater share of their lifetime in retirement than any other generation before (Tyers & Shi, 2007). At the same time, one can observe growing flexibility in the retirement process in western countries. Emerging trends such as bridge employment (i.e., any paid work after receiving a pension) lead to greater variability in the retirement process and give older workers more control in arranging their own retirements (Shultz & Olson, 2012). These upcoming dynamics in retirement offer new opportunities to study retirement-related factors that may influence health, and more specifically cognitive health.

Retirement usually occurs around the same age as when the first age-related cognitive declines are observed (Salthouse, 2012). Good cognitive functioning in old age is crucial for older adults' quality of life (Stites, Harkins, Rubright, & Karlawish, 2018). Understanding critical periods for cognitive functioning in later life is therefore of great importance. To address current demographic challenges while promoting (cognitive) health it is crucial first to understand the possible impact retirement has on cognitive functioning. Furthermore, cognitive functioning determined early in life may affect adaptation to retirement and well-being after retirement. Although research on these topics has been growing in recent years, the relationship between retirement and cognition is still not fully understood.

In 2015, the HEalth, Aging and Retirement Transitions in Sweden (HEARTS) study (Lindwall et al., 2017) was launched. This study aimed to improve the understanding of the influence of retirement on different aspects of psychological and cognitive health. Various sociodemographic, work- and retirement-related, health, lifestyle, and psychological- and cognitive-health data were collected in a longitudinal design. This thesis is written as part of the HEARTS program, supported by the Swedish Research Council for Health, Working Life and Welfare (Dnr 2013-2291), and the analyses presented as part of **Studies II** to **IV** are based on the HEARTS dataset. In the four studies included in this thesis, we study cognitive aging in relation to retirement while applying a life-span perspective. Below, I will first introduce theoretical considerations and empirical findings regarding cognitive aging and retirement. I will then present the four studies that are the basis of this thesis. I will finally discuss the four studies in relation to my overall research questions, addressing their theoretical and practical implications.

COGNITIVE AGING

The last 50 years of cognitive aging research have led to an advanced understanding of cognitive functioning and changes that occur during aging (Anderson & Craik, 2017). In this chapter, I give an overview of cognitive aging, starting with defining what cognition is, how it is described in the aging literature, including different cognitive aging theories, IQ determined early in life, how different cognitive abilities change in older age, and, finally, the challenges of studying cognition over the life-span.

Cognition can be defined as "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" (Oxford Dictionary, 2019). These mental actions incorporate various cognitive abilities, which can be classified in different ways. A traditional broad classification of cognitive abilities distinguishes between the domains of crystallized abilities (or pragmatics) and fluid abilities (or mechanics; e.g., Baltes, 1993). However, a general intelligence factor (*g*) is assumed to underlie all cognitive abilities (Spearman, 1904). Crystallized abilities refer to abilities and knowledge that have been accumulated over the life-span, such as verbal fluency and general knowledge. Fluid abilities, in contrast, comprise processing and reasoning abilities such as problem-solving and spatial abilities, episodic memory, cognitive flexibility, processing speed, and attention (Leal & Yassa, 2019). Changes in cognition – mostly declines – as part of the normal aging process have been documented and discussed several times in the literature (e.g., Salthouse, 2010). Those changes can occur differently in different cognitive domains and abilities. However, fluid abilities start to decline earlier than do crystallized abilities (e.g., Rönnlund, Nyberg, Bäckman, & Nilsson, 2005; Schaie, 2008; Willis & Schaie, 2006).

Cognitive Aging Theories

Human aging starts with conception and ends with the individual's death. Aging is consequently something that occurs throughout one's life. It is therefore necessary to consider more than just a specific period of life, but instead the whole life-course[1] in order to understand aging processes and specifically cognitive aging. In line with this conceptual understanding of

[1] In this thesis, I use the terms "life-span" and "life-course" interchangeably, although it has been argued that they differ slightly – specifically, "life-span" may have a stronger connotation of the length of life (Alwin, 2013). However, because both terms have been used with reference to similar theories (e.g., Mayer, 2009), I will treat them identically.

aging, the so-called life-span perspective on human development has been suggested (Baltes, 1987; Baltes, Reese, & Lipsitt, 1980). This theoretical framework assumes that human development is a lifelong process that entails behavioral changes throughout the life-course. These changes occur in different domains (e.g., biological, physical, social, and cognitive), and – importantly – in interrelated contexts such as cultural, societal, and personal settings (Boyd & Bee, 2015). In other words, the overarching idea of a life-span perspective is that biological processes and genetic constitutions determine human development to a certain extent, while social and environmental factors, as well as individual experiences and their interactions with one another, determine further development. Human development is therefore characterized by plasticity (Baltes, Lindenberger, & Staudinger, 2007). Development can furthermore occur at any point over the life-span and does not necessarily need to be unidirectional or linear, but can be best described in terms of a multidirectional, multidimensional process (Baltes et al., 1980). Thus, developmental trajectories are intra-individually variable, shaped by processes of acquisition, maintenance, transformation, and extinction (Baltes et al., 1980). Growth as well as decline are thus part of human development (Baltes, 1987). As already indicated, plasticity in development is a key concept. This means that trajectories of development are assumed to be affected and modifiable by individual experiences (Baltes, 1987). Although many developmental changes usually occur at certain ages (e.g., language acquisition in childhood), chronological age is not a causal agent, but rather an index of the passing of time since birth. Potential causal explanations for developmental phenomena refer to numerous biological, psychological, and social influences, as well as to their interactions. In particular, non-normative critical life events (e.g., career changes) and normative history-graded influences (i.e., cohort-specific experiences such as economic depressions) are seen to influence individual trajectories (Baltes & Willis, 1979).

The idea of life-span development related to cognitive development provides a basis from which to describe and possibly explain intra- and inter-individual differences in cognitive trajectories over the life-span, including individual and normative experiences that potentially shape cognitive development (Schmiedek, 2017).

In this context, specific theories have been proposed to explain inter-individual differences in cognitive aging, including models focusing on behavioral or neural aspects (for an overview, see Dennis, Gutchess, & Thomas, 2020). One theory that combines different aspects of these models is the *Scaffolding Theory of Aging and Cognition* (STAC; Park & Reuter-Lorenz, 2009). Its basic assumption is that so-called scaffolding processes help to protect and maintain brain functioning in older age. This is based on evidence that the brain undergoes potentially function-threatening, age-related changes such as volume shrinkage, decreases in white matter integrity and the number of dopamine receptors (e.g., Davatzikos & Resnick, 2002; Dreher, Meyer-Lindenberg, Kohn, & Berman, 2008; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; for an overview, see Goh & Park, 2009). In particular, scaffolding refers to compensatory processes, such as enhanced activity, connectivity strengthening, or recruitment of new brain regions, which are initiated to compensate for the decline in certain brain functions due to aging (Goh & Park, 2009; Park & Reuter-Lorenz, 2009). In the revised version of the STAC (*STAC-r*), a life-course perspective on cognitive aging was introduced. This entailed the inclusion of different life-course experiences, emphasizing their importance for neural enrichment, but also for potential neural depletion (Reuter-Lorenz & Park, 2014). Neural enrichment refers to factors such as intellectual engagement, education, higher initial cognitive ability (i.e., measured early in life), and physical fitness that directly or indirectly (through a positive effect on brain structure and function) increase compensatory scaffolding capacity. Both enhanced brain structure/function and scaffolding capability are then related to higher levels of cognitive functioning as well as slower rates of cognitive decline. In contrast, depletion factors such as chronic stress, depression, scoring high on the personality trait of neuroticism, lower socioeconomic status, and vascular diseases impede brain functioning as well as scaffolding processes, leading to worse cognitive functioning and faster cognitive decline. Other aspects assumed to have a direct positive effect on compensatory scaffolding capacity are various forms of interventions. These include learning new skills, social and intellectual engagement, exercise, cognitive training, as well as meditation. The STAC-r is supported by empirical evidence of many of its suggested ideas (for an overview, see Reuter-Lorenz & Park, 2014). For example, early life social circumstances were shown to influence cognitive aging (Osler, Avlund, & Mortensen, 2013), and engagement in leisure and physical activities in certain periods of adulthood were also found to affect how cognition changes over the lifetime (e.g., Gow, Pattie, & Deary, 2017). I will further discuss the empirical basis of the STAC-r during this thesis, specifically in the section *Factors in Relation to Cognitive Aging and Retirement*.

Closely related to the idea of the compensatory scaffolding are the concepts of brain or cognitive reserve and brain maintenance. The concept of reserve has its origins in observations by various medical practitioners and researchers (e.g., Katzman et al., 1989; Satz, 1993) who noticed fewer clinical symptoms in certain patients with brain pathology or brain damage than in other patients with similar brain damage (Stern, 2002). Thus, no clear, direct link between the severity of physical damage and resulting performance impairments could be observed (Stern, 2003). Katzman (1993) saw the first explanations for this phenomenon in the larger brain volume of Alzheimer's disease patients with fewer symptoms, and called this phenomenon *brain reserve*. Brain reserve can be classified as a passive reserve model (Stern, 2002). Passive models assume that each person has an individually different brain reserve capacity in terms of brain volume and neuronal count. Functional deficits of brain damage only become evident when they fall below certain threshold, for example, of synaptic density, and brain size (Steffener & Stern, 2012). These assumed thresholds are thereby universally applicable to everybody. In people with a higher brain reserve capacity, these thresholds are never declined below or at a later point in time, resulting in absent or less pronounced cognitive declines. Conclusively, brain reserve refers to preexisting aspects related to the brain itself that help in coping with pathologies (Varangis & Stern, 2020).

In contrast, the concept of *cognitive reserve* can be understood as an active reserve model. It assumes that all cognitively stimulating, but also physical, and social activities during a person's life can build up a buffer that helps to delay cognitive decline. This buffer is seen as accumulating over the whole life-span, with educational and occupational attainment being of special importance (Barulli & Stern, 2013; Stern, 2002, 2003). Active reserve models assume that the brain actively deals with brain damage mainly by applying the mechanisms of neural reserve and neural compensation (Stern, 2006). Neural reserve refers to the more efficient use of neural networks, resulting in more efficient cognitive processing (Richards & Deary, 2005). Higher neural reserve based on greater neuronal capacity, efficiency, and flexibility allows cognitive processes to remain functional despite potential disruptions (Steffener & Stern, 2012). Stern (2002) noted that the most important difference between neural compensation and neural reserve is that the former only occurs as a specific response to brain damage and not in healthy individuals. Neural compensation thus means the use of other neuronal networks or brain structures instead of the impaired standard ones in order to perform a specific cognitively demanding task. Individuals with a higher reserve are assumed to be able to recruit alternative neural networks and brain structures to uphold certain functions. This idea is in line with compensatory models of aging, such as the *Hemispheric Asymmetry Reduction in Older Adults* (HAROLD) model (Berlingeri, Danelli, Bottini, Sberna, & Paulesu, 2013) or the *Posterior-Anterior Shift in Aging* (PASA) model (Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008), which assume that the recruitment of additional brain regions leads to improved performance in older than younger individuals. Conclusively, cognitive reserve refers to the development of more flexible and adaptive cognitive networks as a result of cognitive stimulation over the life-span (Varangis & Stern, 2020).

Although the idea of cognitive reserve has been prominent in cognitive aging research, Nilsson and Lövdén (2018) noted difficulties in the operational definition of cognitive reserve. Operationalizability is assumed to be a necessary condition for a scientific concept as part of a scientific theory in some theory of science traditions (e.g., Bridgman, 1927). Accompanying difficulties in the measurability of a concept may in turn impede the falsifiability of a theory (often seen as an important criterion of a scientific theory; see, e.g., Popper, 1934). However, others would argue that operationism is a too rigid requirement for any scientific theory (for further discussion, see Leahey, 1980). Despite this debate, the concept of cognitive reserve has initiated several empirical studies. Of these studies, most found that educational and occupational attainments were associated with cognitive levels in older age, though not necessarily with cognitive changes in healthy older adults (Lane, Windsor, Andel, & Luszcz, 2017; Lenehan, Summers, Saunders, Summers, & Vickers, 2015). Some studies also found interactive or additive effects of described experiences on cognition (e.g., Hurst et al., 2013).

One concept that is complementary to the passive and active reserve models, the concept of *brain maintenance*, was suggested by Nyberg, Lövdén, Riklund, Lindenberger, and Backman (2012). This concept emphasizes genetic factors, existing neurobiological resources, or lifestyle factors that protect against pathology and age-related declines. Instead of trying to explain how the brain deals with existing pathology (i.e., reserve), the concept of brain maintenance concentrates on processes allowing the brain to continue to function in old age (i.e., maintaining its prior chemistry, structure, and function), which in turn are assumed to explain inter-individual differences in cognitive changes in older age (Nilsson & Lövdén, 2018). Nilsson and Lövdén (2018) argued that brain maintenance (i.e., changes in the brain) can be operationalized in a more reliable way (despite its limitations) than can cognitive reserve and is therefore a more useful concept to apply in research on cognitive change over the life-span.

The cited concepts clearly concern the question of whether cognitive functioning and cognitive decline is modifiable over the life-span or whether cognitive functioning in older age is solely determined by genetic and biological factors (i.e., early in life). Referring to that question, the hypotheses of *preserved differentiation* and *differential preservation* (Salthouse, 2006) have emerged. Preserved differentiation refers to the idea that preexisting differences in functioning persist over time, meaning that levels of functioning in older age are mainly determined by earlier levels of functioning. In contrast, differential preservation assumes that inter-individual differences in remaining cognitive function in older age occur due to differences in engagement in mentally stimulating activities. Thus, cognitive stimulation over the life-span is assumed to alter cognitive trajectories.

Corresponding to the idea of differential preservation, the use-it-or-lose-it hypothesis (also referred to as the mental-exercise hypothesis; Salthouse, 1991, 2006) assumes that continuous intellectual activity and mental challenges are needed to maintain cognitive abilities. By engaging in cognitively stimulating activities and pursuing an active lifestyle, brain functioning may be preserved even in older age (Hultsch, Hertzog, Small, & Dixon, 1999). Cognitive stimulation here refers to a broad range of activities that stimulate memory and thinking (Woods, Aguirre, Spector, & Orrell, 2012). However, although intuitively plausible, methodological and theoretical issues have made the empirical examination of the hypothesis challenging and have probably contributed to scattered findings concerning its accuracy. These challenges include the operationalization of activity measures, the directionality and temporal order of activity engagement and cognitive functioning as well as how different cognitive domains are affected (Bielak, 2010; Salthouse, 2006).

In conclusion, how lifetime experiences and lifestyle are related to cognitive levels and changes is still not fully understood, but we do know that individual experiences are potential confounding or explanatory factors that need to be considered when studying cognition and aging.

IQ Determined Early in Life

The term IQ is the abbreviation for intelligence quotient and refers to an estimation of human intelligence derived from scores on intelligence tests. In their literal meaning, IQ values indicate the relative test performance of an individual on a standardized distribution originating from a norm population (Stern, 1914). However, in many (research) contexts, as in this thesis, the term IQ is used to mean the same as *g* (Spearman, 1904), i.e., as an estimate of general cognitive ability.

IQ is one of the most stable abilities within a person over the life-span. Stability estimates of about .90 or higher have been reported, with IQ measured at age 18 accounting for up to 74-90% of the variance in IQ 32-47 years later (Rönnlund, Sundström, & Nilsson, 2015). Another study found the estimated stability of IQ to be .67 from age 11 to age 90 (Deary, Pattie, & Starr, 2013). Higher IQ determined early in life has also been related to less cognitive decline before death and higher dementia risk (Cadar, Robitaille, Pattie, Deary, & Muniz-Terrera, 2020; Foverskov et al., 2020; Nyberg et al., 2014).

The reported stability of IQ could be seen as support for the existence of brain reserve, meaning that genetic factors or neurobiological resources, rather than acquired resources (i.e., cognitive reserve), shape IQ trajectories. However, it is also possible that IQ is preserved by the mechanism of brain maintenance. Because higher early IQ has been associated with decreased dementia risk (Foverskov et al., 2020; Nyberg et al., 2014), it could also be argued that higher IQ early in life may help to acquire a (cognitive) reserve that helps to prevent or delay pathology-related cognitive decline. Following the life-span perspective (Baltes et al., 1980), early life experiences may shape individual development and thereby affect various outcomes in later life. Accordingly, research has shown that IQ measured in childhood or early adulthood is a factor that could explain some of the inter-individual differences in different outcomes in old age. For example, a range of studies reported positive associations between early-life IQ and different health outcomes such as cardiovascular health, physical fitness, survival (in contrast to mortality), and psychological health (Aberg et al., 2009; Ariansen et al., 2015; Batty, Mortensen, & Osler, 2005; Calvin et al., 2011; Kajantie et al., 2010; Lager, Seblova, Falkstedt, & Lövdén, 2017; Meincke et al., 2014; Meincke, Osler, Mortensen, & Hansen Å, 2016; Poranen-Clark et al., 2016). Other outcomes later in life such as income or socioeconomic position were also related to higher IQ in childhood (Furnham & Cheng, 2016; Lager et al., 2017). One idea behind these positive relationships is that individuals with higher initial IQ may engage in more favorable health behaviors. They furthermore may have a higher likelihood of finding themselves in more positive and supportive occupational and social environments, helping them maintain their health status and nourishing their (financial) well-being (e.g., Whalley & Deary, 2001).

Studying IQ determined early in life and different outcomes later in life requires longitudinal data that span multiple decades, which are often inaccessible. However, a unique opportunity to study IQ early in life is presented by data from military conscription. In many countries, such as Sweden, men had to undergo examinations to test their suitability for military training. These examinations entailed basic measurements of cognitive functioning (Carlsted & Mårdberg, 1993; Carlstedt, 2000). By connecting these data to studies conducted decades later, it is possible to link information on early-life IQ to data from individuals' later life. The HEARTS project is one study that is linked to conscription data, enabling study of the relationship between early life IQ and outcomes later in life, which was the focus of **Study IV**.

Age-Related Changes in Cognitive Abilities

Leaving general IQ and focusing on a more precise classification of cognitive abilities, it can be noted that the latter can be described in many ways (besides the broad categorization as fluid vs. crystallized abilities). In this section, I give a short overview of age-related changes in some of the abilities that were required to complete the cognitive tasks in **Studies II** and **III**.

Perceptional and processing speed components, both of which decline with age, are required to complete most cognitive tasks (Murman, 2015; Verhaeghen, 2013). Reduced processing speed has especially been found to partially explain poorer test performance in older age (Salthouse, 1996).

Memory abilities are commonly divided into declarative and non-declarative (Harada, Natelson Love, & Triebel, 2013). Age-related declines can be observed especially in declarative memory functions. For example, episodic memory (e.g., autobiographic experiences) and semantic memory (e.g., information, practical knowledge, and language usage) are negatively affected by age. Episodic memory starts to decline earlier than semantic memory, and the latter can even increase into higher ages (Rönnlund et al., 2005), while non-declarative memory functions such as recognition or procedural memory can remain unaffected throughout the life-span (Lezak, Howieson, Loring, & Fischer, 2004).

Various related cognitive functions such as inhibitory and attentional processes, cognitive flexibility, and working memory abilities are often summarized under the term "executive functions." The term also refers to higher-order functions such as problem-solving or reasoning ability (Diamond, 2013). Working memory as a major aspect of executive functions comprises simultaneously storing and processing or transmitting information (Baddeley, 1992). In simple working memory tasks, only slight differences in performance can be observed between younger and older adults, while in more complex tasks such as reading or operational span tasks, greater differences appear to the advantage of younger adults (Verhaeghen, 2013). As it is difficult to separate working memory from attentional processes (Balota, Dolan, & Duchek, 2000), a similar pattern can be observed for attention tasks in healthy older adults. The ability to complete simple attention tasks can remain intact into higher ages, whereas more complex attention tasks requiring divided or selective attention are more likely to decline in older age (Carlson, Hasher, Zacks, & Connelly, 1995; Salthouse, Fristoe, Lineweaver, & Coon, 1995). Longitudinal studies also suggest a decline in reasoning abilities in older ages, although later than suggested by cross-sectional studies (Rönnlund, Lövdén, & Nilsson, 2008; Singh-Manoux et al., 2012). Most research agrees that age-related cognitive changes that appear on a behavioral level reflect structural and functional changes in the brain that occur during aging (Cabeza, Nyberg, & Park, 2016; Reuter-Lorenz & Cooke, 2016).

While episodic memory, executive functions, verbal fluency, spatial abilities, and numeracy are considered in **Study I**, **Studies II** and **III** focus on one specific aspect of episodic memory (i.e., memory recognition) and reasoning ability.

There are ongoing discussions of whether pathology-related developments such as different forms of dementia are part of the normal aging process. However, they mainly occur among older people (Prince et al., 2013; Wilson, Wang, Yu, Bennett, & Boyle, 2020). Compared with healthy older adults, people with dementia often exhibit behavioral differences and diverging underlying changes in the brain (Lyketsos et al., 2011; Wyss-Coray, 2016), but these pathological cognitive changes are not addressed here.

Studying Cognitive Aging

Challenges in studying cognitive aging can include both general biases and biases that are more specific to certain study designs.

General Biases

Some general biases in most studies of cognition concern the recruitment of participants. The usual recruitment procedures in population-based studies (e.g., via mail) tend to select only people with a certain functional level of cognition to participate. This bias can restrict the representativeness of the sample and underestimate the prevalence of cognitive decline in a certain sample (Murman, 2015). Second, misclassification bias entails classifying a person who has a disease as healthy (Murman, 2015). Investigating healthy age-related cognitive decline in a sample that includes both healthy participants and those with pathological cognitive changes can lead to unreliable conclusions and overestimated negative effects. However, as the prevalence of pathology is higher in the older than the general population (Alexander et al., 2015) and as the line between healthy and pathology-related aging may not be clearly defined (Wilson et al., 2020), it might be fair to include people with pathological changes if the study is intended to illustrate population-based patterns.

Study Design Biases

Different biases can be related to the characteristics of a study, including cohort effects. Cross-sectional study designs are especially prone to cohort effects, but the latter can also appear in longitudinal study settings (Rönnlund et al., 2005). Educational opportunities in all parts of the world, especially for women, have risen dramatically since the second half of the last century (Barro & Lee, 2013). At the same time, in western countries, industrial and manufacturing jobs have declined in the past 50 years, while service sector employment has steadily increased (OECD, 2018). Rapid technological development and digitalization in diverse occupations have also created greatly different between-cohort work experiences (Susskind & Susskind, 2015), making them much less comparable. These generational educational and occupational differences could directly influence cognitive functioning, making them relevant to consider when studying cognition in different cohorts.

In general, the research question should guide the decision on which study design to use. To investigate relative functioning between different people at a certain time point, cross-sectional data are helpful (Salthouse, 2012). Because of possible cohort effects, however, it can be preferable to investigate intra-individual trajectories and changes in cognition over several different time points using cross-sequential (or similar) study designs.

However, longitudinal study settings are prone to some other biases, including retest effects in which performance improve in repeated cognitive tests due to individual learning rather than an actual enhancement of ability (Thorvaldsson, 2015). Additionally, the generalizability of longitudinal study results can be reduced due to selective attrition, in which participants who drop out of studies over time are usually those showing poorer (cognitive) performance (Baltes, Schaie, & Nardi, 1971; Schaie, Labouvie, & Barrett, 1973).

Differences between cross-sectional and longitudinal studies may also have a great impact on study findings and inferences. Evidence from cross-sectional studies in particular suggests earlier onset of declines with age in reasoning ability (and most other cognitive domains). For example, the time point of the reported onset of cognitive decline depended greatly on whether inter-individual (i.e., cross-sectional) or intra-individual (i.e., longitudinal) data were analyzed in the BETULA study (Rönnlund et al., 2005). While in cross-sectional analyses the decline is seen to start at an age younger than 35, longitudinal data analyses that were practice-adjusted revealed the onset at around age 60. When considering studies with longitudinal designs, cognitive declines are less pronounced (or even reversed, i.e., learning) in individuals in the same age ranges as the HEARTS sample, even when controlling for possible practice effects (Rönnlund et al., 2005, 2008; Rönnlund & Nilsson, 2006; Schaie, 1996). These differences can be explained by factors such as selective attrition or educational differences between the compared cohorts. Especially in women, cognitive decline is often overestimated in cross-sectional designs, because their cohort differences in educational attainment are even bigger than men's (Singh-Manoux et al., 2012). This empirical example highlights the importance of following individuals over time to investigate cognitive trajectories independent of cohort-related differences. In line with the life-span view of cognition, longitudinal study designs with multiple birth cohorts are therefore preferred.

RETIREMENT

Retirement is an important life transition involving changes in many domains of life, such as roles, everyday life, and routines, and it often entails fewer demands and more freedom for the retiree. Although retirement is one of the major life events that most people will eventually experience in their adult life, early research on retirement has mainly focused on the financial and physical well-being aspects of retirement, and less on the psychological aspects. This has changed drastically in recent years, mainly because researchers from areas such as psychology or sociology have seen the opportunities to better understand human functioning and psychological processes related to one of the major life transitions (Wang, 2013).

In this chapter, I focus on retirement as a construct. First, I introduce the concept of retirement, then focus on retirement theories, adaptation to retirement and life satisfaction over the retirement transition. Finally, I briefly present the Swedish retirement context.

The Concept of Retirement from a Psychological Perspective

Retirement has been characterized as the entry into the "third age" (Jonsson, 2011; Laslett, 1991), which is also considered the golden years of adulthood, as it is a time in which age-imposed physical, emotional, and cognitive limitations often have not yet started to adversely affect individuals' everyday lives (Rubinstein, 2002). Instead, "for those with adequate resources, adequate health, and few responsibilities, this period provides a context for self-fulfillment, freedom, and purposeful engagement that is largely new in human history" (Rubinstein, 2002, p. 30).

The term "retirement" involves several factors and has been defined in various ways in the retirement literature. The definitions range from "nonparticipation in the labor force" to "receiving pension income" and "exit from the main employer" (Denton & Spencer, 2009). From a psychological perspective, retirement has mainly been conceptualized as a process (Wang & Shi, 2014). It can be understood either as a decision-making process, implying a voluntary exit from work, which is not invariably the case, or as a career development stage (Shultz & Wang, 2011). Viewing retirement as a career development stage highlights the career potential of older adults and implies that retirement can entail further individual growth in a time supposedly dominated by withdrawal and decay (Wang, Zhan, Liu, & Shultz, 2008). In addition, retirement has been conceptualized as a long-term adjustment developmental process (Wang, Henkens, & van Solinge, 2011). Various aspects, such as factors specific to the retirement transition, life after retirement, and, specifically adaptation to retirement, are of special interest from such a perspective (Shultz & Wang, 2011). Adjustment and adaptation to retirement will be further discussed in the section *Retirement Transition and Adaptation to Retirement.*

The retirement process usually entails three different sequential phases. The first phase concerns the time before retirement (i.e., pre-retirement), which is typically occupied with occupational life as well as planning of the individual retirement. The second phase concerns the decision-making phase, which is characterized by concrete choices concerning the individual retirement (e.g., at what age to retire). The third phase comprises the retirement transition and the time after retirement (i.e., post-retirement). Especially in contrast to the pre-retirement time, this phase often entails great changes in daily activity, usually with more time to spend in leisure activity (Wang & Shi, 2014). However, partial withdrawals from the labor force as well as returns to work after retirement or bridge employment (i.e., any paid work after receiving a pension) mean that not all individuals experience these sequential processes (Beehr & Bennett, 2007; Beehr & Bowling, 2012). Instead, individual retirement trajectories with patterns of being retired, unretired, and re-retired have been reported (Hansson, 2019). The idea of viewing retirement as a process that includes different phases, decisions, and experiences interacting with one another and that span over a longer period closely relates to the life-span perspective (Baltes, 1987; Baltes et al., 1980; see the section *Cognitive Aging Theories*).

In the following section, I will expand on the psychological view of retirement adaptation and life satisfaction in the retirement transition.

Retirement Transition and Adaptation to Retirement

Retirement adjustment can be defined as the process of getting used to and comfortable with the changes occurring when leaving working life and retiring (von Bonsdorff & Ilmarinen, 2013). Retirement adjustment therefore entails aspects of the retirement transition itself as well as individual development after retirement (Wang & Shultz, 2010). How individuals adjust to retirement and what factors are of special relevance to successful adaptation can be considered from various theoretical perspectives.

Taking a continuity theoretical view (Atchley, 1989, 1993), retirement can be characterized by stable patterns of behavior, thinking, and feeling despite the changes in many aspects of life (Atchley, 1989). Continuity in aspects such as leisure activity or social relationships is seen to constitute an adaptive strategy for coping with changes in other significant parts of older people's lives (i.e., working life), so that most individuals should easily adapt to retirement when keeping the other domains constant (Van Solinge, 2013). In contrast, the role theory assumes that the change in roles (i.e., from being a working individual to a retired individual), specifically, the loss of the working role, can lead to challenges in adjustment (see, e.g., Ferraro, 2006). However, heterogeneity in adaptation success is expected due to differential experiences of the importance of the working role and how well the role can be replaced after retirement (Van Solinge, 2013).

As indicated above, the retirement process can be understood in the context of a life-span developmental perspective, as can the adaptation to retirement. Elder, Johnson, and Crosnoe (2003) highlighted different life-span factors that may explain inter-individual differences in retirement adjustment. These factors include transition-inherent aspects (e.g., abrupt vs. gradual retirement), the social and normative context (e.g., spousal retirement timing, and normative retirement age), interconnectedness between the life spheres of work and leisure, and how much agency (i.e., opportunity to make one's own decisions) individuals have concerning their own retirement planning and transition (Van Solinge, 2013). All these factors may affect how well an individual can adjust to being retired to differing extents.

Additionally, the theory of Selection, Optimization, and Compensation (SOC; Baltes & Baltes, 1993; Baltes & Carstensen, 1996) within the life-span theoretical framework may help to understand specific adaptations needed to successfully adjust to retirement. The SOC theory assumes that limitations in individuals' resources require the behavioral strategies of selection, optimization, and compensation (Baltes & Rudolph, 2013). Selection refers to one's ability to identify and set individually important goals and thereby choose to pursue aspects of life that are of personal value, when opportunities and losses arise. Optimization relates to the means necessary for achieving the set goals, including strategies such as learning or adjustments in the environment. Compensation refers to using alternative strategies to achieve a desired goal when losses in ability mean that the usual strategies can no longer be applied. Deploying any of these strategies would, according to the SOC theory, ease retirement adjustment (Baltes & Rudolph, 2013). The life-span perspective as presented in the context of the different retirement adjustment theories underlines that the retirement transition constitutes a part of an individual's life that is affected by the individual's surrounding and his/her own decisions and actions.

A theory that combines different aspects of the presented theories is the resource-based dynamic model (Wang et al., 2011). This model explains the processes of adjusting to retirement by assuming that changes in well-being over the retirement transition depend on changes in individual resources (i.e., physical, cognitive, motivational, financial, social, and emotional resources). The availability of and access to more of the individual resources would allow for an easier adjustment. An increase in resources would be directly associated with increases in well-being (for an overview, see Hansson, 2019). Resource availability is, however, determined by antecedents on the macro level (e.g., societal norms and government policies), meso level (i.e., organizational level, e.g., organizational climate; job level, e.g., job characteristics; and household level, e.g., marital quality), and individual level (e.g., health behaviors and psychological resilience). Conclusively, the model implies that resource availability may vary depending on experiences over the life-span (Wang et al., 2011).

Life Satisfaction and Retirement

How people evaluate their own well-being is crucial when trying to understand the individual's success in retirement adjustment. Life satisfaction is a well-established operationalization of subjective well-being and has been used in many studies investigating retirement adjustment (e.g., Calasanti, 1996; Dingemans & Henkens, 2014; Hansson, Buratti, Thorvaldsson, Johansson, & Berg, 2019; Pinquart & Schindler, 2007). The construct combines aspects of emotional as well as cognitive assessments and experiences and is intended to capture an overarching evaluation of well-being (Diener, 1984; Diener, Suh, Lucas, & Smith, 1999). Longitudinal studies suggest that, on average, life satisfaction increases over the life-span and peaks around the age of 65, decreasing afterwards, but with great inter-individual differences in the rate of change (Mroczek & Spiro, 2005). Life satisfaction seems to change differently in relation to different major life events (Luhmann, Hofmann, Eid, & Lucas, 2012). In relation to the retirement event, the general trend seems to be that life satisfaction is rather stable (Hansson et al., 2017). However, individual trajectories of subjective well-being over the retirement transition seem to differ between individuals, as well as within individuals over time (e.g., Pinquart & Schindler, 2007; Wang, 2007).

Different aspects have been shown to be related to the heterogeneity in subjective well-being trajectories over the retirement transition. These include individual attributes such as age and gender (e.g., Szinovacz & Davey, 2005; Szinovacz & Washo, 1992). Furthermore, inter-individual differences and intra-individual change in resources, as suggested by the resource-based dynamic model, seem to be most relevant when explaining variation in subjective well-being trajectories over the retirement transition (e.g., Hansson, Buratti, Johansson, & Berg, 2019; Hansson, Buratti, Thorvaldsson, et al., 2019; Hansson et al., 2017). Two domains of resources, i.e., cognitive and social resources, will be further discussed, as they will be of special interest in **Study IV.**

Cognition and IQ Determined Early in Life

Studies of older adults suggest weak (Allerhand, Gale, & Deary, 2014; Jones, Rapport, Hanks, Lichtenberg, & Telmet, 2003; Llewellyn, Lang, Langa, & Huppert, 2008) or no relationship (Hoppmann, Infurna, Ram, & Gerstorf, 2015) between cognition and well-being. However, these studies did not specifically target the retirement transition and did not include measures of cognitive functioning in early life. So, cognition may indeed be important, because specifically in the retirement transition, good cognitive functioning could act as a resource for individuals needing to cope with changes in their lives. More cognitive resources could consequently be a factor promoting greater well-being when retiring. In detail, positive effects may arise through developing coping strategies over the life-span, meaning that individuals with higher IQ levels determined early in life may acquire a range of coping strategies over their life-span that they can apply to possible challenges related to aging (Bain et al., 2003). Coping is defined as efforts to manage outer and inner demands and potentially stressful situations, including behavioral as well as cognitive components (Lazarus & Folkman, 1984). Specifically, coping strategies can involve various aspects such as support-seeking, problem-solving, distraction, and escape (for an overview, see Skinner & Zimmer-Gembeck, 2007), many of which demand good cognitive functioning. The availability of these coping resources in turn positively affects well-being in older age (Hamarat, 2001). In line with this, one study reported that higher childhood IQ was directly associated with higher quality of life in older adults (Bain et al., 2003).

It is furthermore possible that higher initial IQ increases the chances of pursuing careers with working and retirement conditions promoting life satisfaction later in life. These jobs may offer greater economic security when retiring (Heybroek, Haynes, & Baxter, 2015) or arrangements such as bridge employment (Dingemans & Henkens, 2014), both of which have been shown to foster life satisfaction after retirement.

However, the evidence concerning the relationship between childhood IQ and life satisfaction later in life is inconclusive. One study reported that higher childhood cognitive ability at age eight was related to poorer life satisfaction in early old age (Nishida, Richards, & Stafford, 2016). People of higher intelligence could be more aware of alternative lifestyles or have more pronounced striving for greater achievement compared with people of lower intelligence (Diener, 1984). Adaptations to changes related to growing old and experiences of non-success in achieving certain goals may therefore lead to poorer psychological well-being (Wang, Li, Sun, Cheng, & Zhang, 2017). Contradicting that, some studies do not indicate a strong positive relationship between intelligence and striving for achievement per se (Bergold & Steinmayr, 2018). In addition, another study reported no association between cognitive ability at age 11 and satisfaction with life at age 80 (Gow et al., 2005). It is therefore possible that the association between childhood IQ and life satisfaction in later life is non-existent or occasional. Alternatively, higher IQ may lead to better coping and psychological well-being in certain situations, while in different situations the relationship might be reversed. Besides cognitive abilities, social contacts are seen as resources facilitating the adaptation to retirement (Wang et al., 2011).

Social Relationships

Supportive social relations promote life satisfaction and greater well-being in retirement (Goldberg, Taylor, Shore, & Lipka, 2008; Price & Balaswamy, 2009; Topa, Jiménez, Valero, & Ovejero, 2017). Social interactions can positively act through direct emotional, instrumental, or informative support, as well as indirectly, for example, through positive effects on self-concept, self-esteem, or feelings of connectedness to society (see Cohen, Gordon, & Gottlieb, 2000). However, leaving one's work place often entails changes in social relations. For individuals whose social engagement has mainly focused on relationships at work, retirement may increase social isolation and could therefore negatively affect well-being (Kail & Carr, 2019). Likewise, changes in social support over the retirement transition have been related to changes in life satisfaction, such that decreased social support was associated with decreased life satisfaction while positive changes predicted an overall increase in life satisfaction (Hansson, Buratti, Thorvaldsson, et al., 2019; Hansson et al., 2020).

Generally, social interactions can include quantitative as well as qualitative aspects. Quantitative aspects involve, for example, the frequency of social interactions or the size of an individual's social network, while qualitative aspects comprise the individual's perception of the quality of social support and the properties of a relationship such as intimacy, trust, or closeness (Reis & Collins, 2000). In a meta-analysis, Pinquart and Sörensen (2000) showed that subjective well-being in older age is apparently more strongly associated with measures of quality of social contacts than with quantity measurements, highlighting that positively perceived relationships especially foster well-being. Furthermore, studies have reported that only support from friends in contrast to support from family and neighbors may be relevant to improved psychological well-being (Kail & Carr, 2019; Pinquart & Sörensen, 2000). The authors argued that friendships are actively chosen and developed through reciprocal engagement, and are therefore not experienced as obligatory, as family and neighborhood contacts may be (Fiori, Antonucci, & Cortina, 2006). It is furthermore likely that friends – versus (non-spousal) family members – are in the same age range, probably retiring at about the same time, which allows friends to share and process the same experiences. Additionally, friendship contacts may enhance the feeling of being connected to society beyond one's own family (Adams & Blieszner, 1995), which could be especially relevant when leaving the work context, which is an important part of society.

Retirement in the Swedish Context

As in many other countries, in Sweden, pensions are part of the social security system. Due to tradition (i.e., Sweden was the first country to introduce state pension benefits for the whole population; SOU, 2012), the Swedish social security system is highly developed and part of a strong welfare state. Nowadays, the total pension income in Sweden is based on three parts, i.e., a public pension, an occupational pension, and private pension savings. Withdrawal of these different parts can be started at different ages and even while still working, at the earliest at age 62 (i.e., public pension). Thus, there is no statutory retirement age in Sweden (König & Sjögren Lindquist, 2016). Swedish workers are legally protected to remain employed until the age of 68. However, to meet the challenges associated with an aging society, both the early retirement age and the legally protected working age have been raised recently and further raises are planned in the coming years (Pensionsmyndigheten, 2021).

The opportunity to combine work and pension has led to the retirement process becoming more flexible in Sweden in recent years, and great heterogeneity in retirement transitions can be observed (e.g., König, Kelfve, Motel-Klingebiel, & Wetzel, 2021). In Sweden, as in many other Western countries, attempts to see career-related potential in retirees and retirement as an additional career development stage have become more prevalent (Wang et al., 2011) – evident in strategies such as reduced work hours before retirement, bridge employment, and returns to former jobs (Beehr & Bowling, 2012). These emerging trends lead to greater variability in the retirement process and give older workers more control in arranging their own retirement (Shultz & Olson, 2012). How to study retirement in the Swedish context in relation to cognitive functioning will be the topic of the next chapter.

COGNITIVE AGING AND RETIREMENT

In this chapter, I first give some background on why it is of interest to consider retirement when studying cognitive aging. Next, I describe cognitive aging and retirement in relation to other variables such as occupational and leisure activities as well as personality. I continue by taking a deeper look at the methodological challenges of researching retirement and cognition. I conclude this chapter by stating the aim of this thesis.

Why is Retirement a Relevant Factor When Studying Cognitive Aging?

The retirement event marks the entry into a transition period that involves changes in everyday life, often including changes in daily cognitive demands. A reduction in cognitive stimulation associated with leaving the work place could, according to the use-it-or-lose-it hypothesis (Salthouse, 1991, 2006), negatively affect cognitive functioning. It is hypothesized that "mental retirement" may accompany retirement from work (Rohwedder & Willis, 2010), which implies that incentives to engage in cognitively stimulating activities may weaken, which could in turn result in accelerated cognitive decline.

Retirement in relation to cognitive reserve could be an important area of study, as cognitive stimulation at work ceases and retirees may or may not have cognitive stimulation outside of their previous work. Retirement, therefore, comes with the potential risk of neglecting one's own reserve. This, in the long run, could foster an earlier onset of pathologies such as dementia, as empirical evidence shows a concurrent positive relationship between higher cognitive reserve and later onset of dementia and other cognitive pathologies (e.g., Clouston, Glymour, & Terrera, 2015; Thorvaldsson, Skoog, & Johansson, 2017). While it has been hypothesized that a high reserve also protects against age-related cognitive decline, newer empirical results indicate that the interaction between lifetime experiences and cognitive changes may be more complex and that the concept of cognitive reserve may not necessarily be suitable for explaining age-related decline (Lane et al., 2017; Lenehan et al., 2015). In line with this and drawing on the concept of brain reserve, one may not expect retirement to have an impact on cognitive functioning, because functioning later in life would be determined by genetic factors or existing neurobiological resources that protect against pathology and age-related declines. From the concept of brain maintenance, it is difficult to conclude whether or not retirement would affect brain functioning.

Referring to the STAC-r, neural-enriching factors such as intellectual engagement may decrease when retiring, having a negative effect on compensatory scaffolding capacity, which in the longer run could negatively affect cognitive functioning. However, so-called interventions such as learning new skills, social and intellectual engagement, and exercise, which retirement may offer the time for, could counteract potential negative effects.

It therefore remains unclear whether and how retirement may affect cognitive functioning, which will be investigated in this thesis.

Factors in Relation to Cognitive Aging and Retirement

According to the life-span perspective on cognitive development, cognitive aging is affected by biological and genetic processes, and can be altered by environmental experiences such as individual lifestyle (Schmiedek, 2017). In addition, retirement is embedded in both societal and personal contexts. From a life-span perspective, people's lives before retirement are assumed to relate to their individual retirement experiences, and possibly also to their cognitive functions before and after retirement. Three aspects that could play an important role in post-retirement cognitive functioning may be the occupational background people retire from, how people spend their free time after retirement, and the personal constitution, i.e., individual personality.[2]

Work Characteristics

Work is an important part of people's lives as it occupies much of their waking time before retirement. It is therefore seen to play an important role in adult development (Andel, Finkel, & Pedersen, 2016; Shultz & Wang, 2011).

Different jobs are characterized by different occupational demands, which can be classified in numerous ways. One of the broadest distinctions is between blue- and white-collar work. Blue-collar work classically refers to manual labor, while white-collar work is mainly office work. More finely graded

[2] Other factors in addition to work demands, leisure activity engagement, and personality, such as transition paths into retirement, may also play an important role in the relationship between retirement and cognition (Carr, Willis, Kail, & Carstensen, 2019). However, these other factors are not the focus of this thesis. Genetics, known to contribute to a relatively large extent to cognitive functioning in old age (Deary et al., 2012; Finkel, Reynolds, McArdle, & Pedersen, 2005), is also not considered here.

classifications are often based on various occupational classification systems, such as the International Standard Classification of Occupations published by the International Labour Organization of the United Nations (International Labour Organization, 2016), the Standard Occupational Classification 2010 from the U.S. Bureau of Labor Statistics (Emmel & Cosca, 2010), or the Dictionary of Occupational Titles (National Research Council, 1980). Either directly applied (such as the ISCO-08) or used as a basis for scales such as the Occupational Complexity with Data, Things, and People (National Research Council, 1980), all jobs included in these classification systems are assigned specific values from which specific demands can be derived. Based on these values, a job can be described along several dimensions including work complexity, necessary skills, and social prestige. Besides these objective measures of job demands, subjective self-reports can be used to describe perceived demands at work. The Copenhagen Psychosocial Questionnaire (Pejtersen, Kristensen, Borg, & Bjorner, 2010), for example, includes questions about cognitive demands at work.

The subject of retirement is inevitably connected to the type of occupation people retire from. Schooler (1984) suggested that a complex (working) environment requires cognitively demanding actions and decisions, which in turn could benefit cognitive functioning through the training and stimulation of meeting work challenges. This idea is in line with the cognitive reserve concept, according to which higher (cognitive) work demands would build up a greater reserve, which would buffer the effects of cognitive decline. Furthermore, the use-it-or-lose-it hypothesis suggests that cognitive stimulation is needed for cognitive functioning, which could be gained through a cognitively stimulating working environment. However, the hypothesis does not explicitly specify how different work demands affect cognition. Therefore, it does not directly allow for any prediction of differential effects of work demands on cognitive functioning after retirement.

Leisure Activity Engagement

Cognitive levels and changes have often been associated with an active lifestyle (e.g., Gow et al., 2017; Klimova, Valis, & Kuca, 2017; Small, Dixon, McArdle, & Grimm, 2012). Specifically engagement in physical (Sofi et al., 2011), cultural (Fancourt & Steptoe, 2018), social (Lee & Kim, 2016; Tomioka, Kurumatani, & Hosoi, 2016), and cognitively stimulating leisure activities (Litwin, Schwartz, & Damri, 2017) has been associated with better cognitive functioning in older age. A positive relationship has also been reported for a combination of these aspects, for example, in the case of activities such as volunteering (Gupta, 2018). However, other studies have not reported an association between leisure activity engagement and changes in cognitive functioning over time (e.g., Bielak, Anstey, Christensen, & Windsor, 2012; Bielak, Cherbuin, Bunce, & Anstey, 2014; Gow, Avlund, & Mortensen, 2014; Sörman, Ljungberg, & Rönnlund, 2018).

Leisure activity engagement in older age may be especially important in light of the activity theory, which assumes that for optimal or successful aging, older people should engage in activities and social interactions (Havighurst, 1961). The actual choice of activities older people engage in can be illuminated from different theoretical perspectives (Dorfman, 2015). The continuity theory suggests a benefit of continuing to participate in pre-retirement activities after retirement (Atchley, 1993). In contrast, the life-span view could suggest that participation patterns may vary after retirement depending on the older person's preferences (Elder et al., 2003). From this perspective, future interests and preferences are generally influenced by earlier developments and might include a range of possibly interesting activities. People will tend to engage in what is most personally meaningful to them, and their evaluations of what activities are meaningful may change after retirement (Dorfman, 2015). The SOC theory (Baltes & Baltes, 1993; Baltes & Carstensen, 1996) also underlines that changes in leisure activities after retirement may be based on prioritizing activities that are personally meaningful and that can be performed even within individual age-related constraints.

Retirement could furthermore allow engagement in more activities than before, especially in newly available leisure time. In line with this, a "honeymoon phase" could occur shortly after retirement, characterized by the new retiree engaging in many different activities (Atchley, 1976).

Leisure activities as a whole after retirement can be more or less cognitively stimulating than one's previous work. Those retiring from less cognitively demanding jobs, who may have had less cognitive stimulation in the work context, could especially profit from engaging in post-retirement leisure activities (Coe, von Gaudecker, Lindeboom, & Maurer, 2012; Mazzonna & Peracchi, 2017). However, empirical evidence suggests that people both continue their pre-retirement leisure activities (Kridahl, 2014) and increase engagement in different activities after retirement (Lahti, Laaksonen, Lahelma, & Rahkonen, 2011; Scherger, Nazroo, & Higgs, 2011). In conclusion, the life-changing event of retirement can entail either the continuation of leisure participation or changes as either increases or decreases in participation.

In light of the hypothesis of differential preservation (Salthouse, 2006), especially leisure engagement that stimulates cognitive functioning may positively affect cognitive trajectories. In contrast, the preserved differentiation hypothesis would not expect leisure activity engagement to notably affect cognitive trajectories, because it assumes that preexisting differences determine cognitive functioning later in life. The latter view would also be in line with the idea of brain reserve. However, leisure activities may be lifestyle factors that help to maintain brain functioning (i.e., brain maintenance). Considering cognitive reserve, retirement may simultaneously pose the risk of not building any more reserve, while allowing the buffer to be extended. As the reserve becomes more important with the emergence of pathological cognitive decline (more likely in older age), stronger long-term cognitive effects could be expected from changes in leisure activities in retirement. According to the use-it-or-lose-it hypothesis, engagement in leisure activities may assure cognitive stimulation when job-related demands fall away. The use-it-or-lose-it hypothesis may therefore be more relevant to predicting the short-term effects of retiring and subsequent changes in leisure activities. In relation to the resource-based dynamic model of retirement adjustment (Wang et al., 2011), leisure activity engagement would constitute an antecedent that may help to maintain (or even improve) cognitive resources, which in turn may result in more favorable cognitive trajectories after retirement. Furthermore, work demands and leisure activity may interact with each other, having differential effects on cognitive trajectories. Referring to the resource-based dynamic model, this could mean that increases in cognitive leisure are more beneficial for people retiring from low cognitively demanding jobs, as these retirees had less favorable occupational antecedents than did retirees from high cognitively demanding occupations.

Both factors, occupational demands before retirement and leisure behavior before and after retirement, seem to be related to cognitive functioning in the retirement transition. The importance of when they affect cognition (i.e., in short term vs. long term after retirement) may vary depending on one’s theoretical perspective. However, besides occupational demands and leisure activity, psychological characteristics may also be related to cognitive functioning in the years around retirement.

Personality

Personality is composed of different personality traits that are enduring, automatic, relatively situationally consistent and distinguish one individual from another (Roberts, 2009; Roberts, Wood, & Caspi, 2008). Personality traits are often identified and measured according to a five-factor model comprising openness, conscientiousness, neuroticism, extraversion, and agreeableness (Goldberg, 1993), also referred to as the Big Five traits. These different factors can be described as follows (Costa, McCrae, & Dye, 1991; McCrae & John, 1992): openness refers to being curious, having wide interests, and being open to new experiences; conscientiousness involves attributes such as being organized, persistent, responsible, and thorough; neuroticism relates to the tendency to be emotionally unstable, worried, tense, and anxious; extraversion refers to being outgoing, sociable, active, and enthusiastic; and agreeableness concerns the tendency to be kind, trusting, compliant, and organized.

Individual differences in personality remain rather stable over the life-span (e.g., Damian, Spengler, Sutu, & Roberts, 2019). However, smaller age-related changes in all personality traits have been reported (e.g., Costa, Herbst, McCrae, & Siegler, 2000; Schwaba & Bleidorn, 2018), though inconsistently among studies. These inconsistencies can mainly be explained by differences in methodological approaches to measuring personality change across the life-span (Damian et al., 2019; Specht, Egloff, & Schmukle, 2011). However, on average, emotional stability tends to increase over the life-span (i.e., neuroticism decreases) and stabilizes around the ages of 60 to 70 (Roberts, Walton, & Viechtbauer, 2006). A similar pattern can be observed for conscientiousness. Probably due to declines in physical and mental health, conscientiousness tends to decrease at around the age of 90 (Lucas & Donnellan, 2011; Specht, 2017a). On average, openness as well as extraversion have a tendency to increase in young adulthood and decrease or stabilize afterwards, while agreeableness remains rather stable until the age of 60 and increases slightly afterwards (Roberts et al., 2006; Specht, 2017a). Some studies have shown that stability in personality can be described as having an inverted U-shape, meaning that middle adulthood is the phase with the greatest stability. Individuals in younger and older adulthood are more likely to experience changes in their personality, although large intra-individual differences exist (Lucas & Donnellan, 2011; Specht et al., 2011).

Both genetic and environmental factors as well as their interaction with each other are assumed to affect the stability or changeability of personality over the life-span (Specht et al., 2011). The mentioned average personality changes over the life-span have been described as a maturation process (Roberts & Wood, 2006) that includes adaptive personality changes to handle developmental tasks in specific life phases (Hutteman, Hennecke, Orth, Reitz, & Specht, 2014). These tasks include rearing children or starting an occupational career in early or middle adulthood. In later adulthood (i.e., 60 years or older), developmental tasks concern adjustment to retirement from work and possibly declining health, which could either co-occur with or lead to changes in personality. In line with this, one study has shown that retiring was associated with small decreases in conscientiousness (Specht et al., 2011). In older age, possible personality changes may also be related to coping with losses, such as cognitive decline (Specht, 2017b). Personality may therefore be an important factor to consider when studying cognition in the time around retirement age.

Some of the between-person variability in cognitive functioning has been explained by inter-individual differences in personality traits. Two meta-analyses have found scattered results for the relationship between cognitive functioning in older adults and the Big Five personality traits (for reviews, see Curtis, Windsor, & Soubelet, 2015; Luchetti, Terracciano, Stephan, & Sutin, 2015). Associations varied in terms of both their direction and magnitude.

However, some consistent patterns can be observed for some of the five personality traits. Concerning openness, most studies reported that higher levels of openness were related to better cognitive functioning (e.g., Austin et al., 2002; Graham & Lachman, 2012). This positive association may be explained by the fact that individuals with pronounced openness may be more prone to engage in many different activities, which could provide cognitive stimulation (Jackson, Hill, Payne, Parisi, & Stine-Morrow, 2020; Stephan, Boiché, Canada, & Terracciano, 2014). Following the use-it-or-lose-it hypothesis, the increased engagement in stimulating activities would then have a positive effect on cognitive functioning. One study, however, has tested the possible mediation effect of leisure activity engagement and found no support for this hypothesis (Soubelet & Salthouse, 2010). Besides these ambiguities, it remains unclear how levels and change in openness relate to changes in cognitive functioning (Curtis et al., 2015).

Another rather conclusive finding concerned higher levels of conscientiousness being related to less steep cognitive decline (e.g., Chapman et al., 2012; Hock et al., 2014; Luchetti et al., 2015), but not with the level of cognitive functioning (e.g., Austin et al., 2002). Possible explanations for this finding may refer to the fact that people scoring higher on conscientiousness tend to engage in healthier lifestyles and health-promoting behaviors, which could passively affect cognitive health in the long term. In line with that, conscientiousness was related to more engagement in physical activity and fewer health-risk behaviors such as smoking (Rhodes & Smith, 2006; Terracciano & Costa, 2004). It is also hypothesized that these individuals have better stress coping skills and more social support, possibly enhancing their cognitive health (see, e.g., Bogg & Roberts, 2013). It remains unclear, however, whether better cognitive functioning helps to maintain higher levels of conscientiousness or whether people become more conscientious (i.e., organized) to counteract possible age-related cognitive declines and to maintain their previous cognitive performance (Curtis et al., 2015).

Concerning neuroticism, some studies have suggested that higher levels of neuroticism are related to lower levels of and greater decline in different cognitive abilities (Chapman et al., 2012; Hock et al., 2014; Wilson et al., 2003). Neuroticism is related to pronounced anxiety, stress, and worry, which might impair test performance in specific test situations (Sutin et al., 2011;

Wetherell, Reynolds, Gatz, & Pedersen, 2002). However, it is also plausible that long-term exposure to chronic stress, which has a relatively higher prevalence among individuals scoring high on neuroticism, could cause permanent neuronal damage, thereby possibly impairing cognitive functioning (e.g., Lupien, McEwen, Gunnar, & Heim, 2009; Sapolsky, Krey, & McEwen, 1986). Other studies have not found any association between neuroticism and decline in cognitive functioning (Hultsch et al., 1999; Wetherell et al., 2002), calling into question the chronic stress hypothesis. Although neuroticism tends to decrease with age (Allemand, Zimprich, & Martin, 2008), between-person variability in changes in neuroticism have been reported for older adults. Increases in neuroticism were particularly related to pathology-related cognitive decline (Yoneda, Rush, Berg, Johansson, & Piccinin, 2016; Yoneda et al., 2018).

The evidence concerning extraversion is less conclusive, because studies report positive, negative, or no association between extraversion and the level of or rate of change in cognition (e.g., Austin et al., 2002; Chapman et al., 2012; Graham & Lachman, 2012; Hultsch et al., 1999). Different possible explanations have been proposed (see Curtis et al., 2015), including extroverts' tendency to get distracted easily, which may diminish test performance (Gold & Arbuckle, 1990). In contrast, positive associations were hypothesized to occur due to enhanced positive affect among extraverts leading to better test performance as well as more engagement in stimulating activities and a more active lifestyle, as suggested for individuals scoring high on openness (Baltes & Smith, 2003; Stephan et al., 2014). However, empirical support for these hypotheses is still conflicting.

Additionally, most previous studies have found no relationship between the level or rate of change of cognition and agreeableness (e.g., Chapman et al., 2012; Luchetti et al., 2015). Associations between agreeableness and cognitive functioning have been examined in many studies to give a comprehensive picture of the cognition-personality relationship. However, a conceptual foundation for the specific link between cognition and agreeableness is missing and may therefore explain why no associations have been found (Curtis et al., 2015).

Studying Cognitive Aging and Retirement

As mentioned, retirement can be defined in various ways. In line with that, studies of cognitive aging and retirement also apply different retirement definitions, operationalize retirement in different ways, and use different analytical approaches. This, in turn, may influence the studies' results. The following section presents considerations of these aspects in studying cognitive aging and retirement.

Retirement Definitions and Operationalizations

In empirical work, the operationalization of retirement varies substantially (Denton & Spencer, 2009). Psychological research commonly uses self-reports to measure retirement-related information (Shultz & Wang, 2011).

When defining retirement, some studies differentiate only between working and retired individuals. Some of these studies exclude participants who are on sick leave, unemployed, or homemakers (Bianchini & Borella, 2016), while others include them in either the working or the retired group (Finkel, Andel, Gatz, & Pedersen, 2009; Roberts, Fuhrer, Marmot, & Richards, 2011). Other studies differentiate between working and not working for pay (Lei & Liu, 2018) as a proxy for retirement. The category of not working for pay, however, may include people who are absent from the labor market for various reasons other than retirement, such as disability, unemployment, or partial retirement (Bonsang, Adam, & Perelman, 2012). Some studies differentiate between three or more categories such as employed, retired, or inactive (de Grip, Dupuy, Jolles, & van Boxtel, 2015), or working full-time, working part-time, or being fully retired (Wickrama, O'Neal, Kwag, & Lee, 2013). Other studies have controlled for a return to work (Bonsang et al., 2012).

Wang and Shi (2014) noted that a match between the conceptualization and operationalization of retirement is crucial in order to correctly interpret research findings. Therefore, when using self-reports on retirement, clear instructions and explanations of how the researchers conceptualize retirement are important. Especially when studying retirement, cognition, and the influence of cognitive stimulation at work, what retirement entails should be clearly defined. Retirement from unemployment could have different effects than retirement from work, as not having been exposed to certain work demands, according to the use-it-or-lose-it hypothesis, might already have had negative effects on cognition. A stronger differentiation between occupational activity and retirement statuses would therefore be advantageous. Furthermore, differential effects of partial, gradual, and abrupt retirement may be expected and have been reported, for example, for life-satisfaction after retirement (Hansson et al., 2017). Recent trends such as bridge employment (Shultz & Olson, 2012) and their possible effects on cognition could furthermore be overlooked if different pathways into retirement are neglected. The number of working hours could also be relevant to consider, as full-time work could involve more responsibilities and therefore more cognitive stimulation than part-time positions. Again, retirement from more demanding positions could affect cognition in different ways than retirement from less stimulating positions.

Another approach to investigating the effects of retirement is to focus on other aspects of retirement such as retirement duration or retirement age. Studies interested in the effects of time in retirement primarily investigate the long-term effects of retirement on cognition (e.g., Bonsang et al., 2012), while studies interested in age at retirement often investigate whether a prolonged working life is beneficial or harmful for cognition in older age (e.g., Vercambre, Okereke, Kawachi, Grodstein, & Kang, 2016).

When investigating time spent in retirement or age at retirement, it is especially important to consider not only the pre-retirement stimulation of job and leisure activities, but also how the time after retirement is spent, especially in leisure activities. The longer the observation period in retirement, the greater the challenge of differentiating between age-related processes and the possible effects of the specific event of retirement, as they might occur simultaneously. The increased likelihood of age-related cognitive decline in older ages (Rönnlund et al., 2005) and the increased variability in cognition between older individuals (de Frias, Lövdén, Lindenberger, & Nilsson, 2007) add to the difficulty.

Study Designs and Biases

Besides the above-mentioned possible biases when studying cognitive aging, other challenges arise in examining the specific effect of the retirement event on cognitive trajectories.

First, the study design (i.e., cross-sectional vs. longitudinal) is important to consider. Typically, cross-sectional study designs use a control group design in a natural setting to compare a group of interest (e.g., retired people) with a control group (e.g., people continuing to work). If both groups have the same characteristics (e.g., same age and education) and differ only in terms of their retirement status, this design would allow the pure effect of retirement on cognition to be differentiated from naturally occurring age-related effects. However, compared with same-aged retirees, people who continue to work likely differ in aspects such as their motivations and opportunities to continue to work (Zappalà, Depolo, Fraccaroli, Guglielmi, & Sarchielli, 2008). Furthermore, better health and higher education have been reported in post-retirement workers than in aged-matched retirees (Kim & Feldman, 2000; Wang et al., 2008). Because health, education, and cognition can interact in a complex way (Clouston et al., 2015), it is difficult to trace possible differences in cognition back to the event of retirement (and not to other differences between both groups). The same applies to studies following participants over a longer period (i.e., longitudinal studies), but still comparing cognitive trajectories between different groups'; for example, comparing people who retire between assessments with people who continue to work or have been retired throughout all measurement points.

A typical bias of many study designs is that of self-selection into retirement or "reversed causality". The decision to retire could be based on the individual's perception that the job tasks have become too cognitively demanding and/or that their cognitive abilities have declined. As a result, the retirement event would be negatively associated with cognitive functioning for this person. This association may be interpreted as a negative impact of retirement on cognition, although self-selection into retirement for cognitive decline reasons has occurred. However, the event of retirement would not immediately have affected the person's cognitive functioning. A causal conclusion as to the effect of retirement based on these results would therefore be problematic.

A possible solution to these challenges would be to examine cognitive changes related to the retirement event using spline models (Marsh & Cormier, 2001). These models allow the modeling of cognitive trajectories for the same individuals before and after retirement so that the individuals are compared with themselves (i.e., within-person comparison), which in turn increases the likelihood of observing changes that are truly related to the event of retirement itself.

Aim of the Thesis

The overall aim of this thesis was to examine cognition in relation to retirement. The first main research question accordingly was: *Does retirement influence cognitive functioning and, if so, what factors may affect this relationship?* We wanted to understand how person-specific characteristics such as occupational demands and personality traits may influence cognitive trajectories in the years around retirement and over the retirement transition. Additionally, we examined the role of leisure activity engagement in post-retirement cognitive trajectories. These research questions were addressed in **Studies I** to **III**.

We furthermore wanted to understand whether cognitive resources determined early in life relate to retirement adjustment. The second main research question accordingly was: *Is IQ, as determined early in life, related to life satisfaction over the retirement transition and is this association moderated by social resources?* This research question was addressed in **Study IV**.

SUMMARY OF THE STUDIES

Study I

Aims and Research Questions

The first study comprised a systematic literature review about cognition and retirement. One systematic review (Meng, Nexø, & Borg, 2017) focused on longitudinal studies published up to December 2016. Because the authors stressed that research in this field was scarce and conflicting, they included only seven studies (Andel et al., 2015; Bonsang et al., 2012; Finkel et al., 2009; Fisher et al., 2014; Roberts et al., 2011; Ryan, 2008; Wickrama, O'Neal, Kwag, & Lee, 2013). Aside from the focus on longitudinal studies, special emphasis was put on studies that included exposures to psychosocial working conditions such as mental job demands. The review found conflicting evidence for the impact of retirement on fluid cognitive abilities. People retiring from jobs with high mental demands and low job strain seemed to decline less in their cognitive functioning after retirement than did those retiring from less mentally demanding and more straining jobs. A different picture was observed for crystallized abilities, for which only weak evidence was found for the negative impact of retirement. The authors noted that the review revealed a major research gap in this field, especially in terms of the mechanisms and various factors that could affect cognition after retirement.

In conducting an updated review of studies of retirement and cognition, we aimed to contribute to the literature by identifying the factors behind the conflicting evidence in the field of retirement and cognition. We therefore investigated different cognitive domains and study characteristics, also aiming to highlight important issues in research on retirement and cognition and to detect gaps in the current research landscape.

Methods

We conducted our systematic literature review following the PRISMA statement (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009), a guideline that includes instructions for objectifying all the steps conducted in the literature search, analysis, and reporting of the results.

The literature search was conducted in the PubMed (n = 563), PsycInfo (n = 359), and Web of Science (n = 382) databases using the following search strings: “retirement AND cognition,” “retirement AND cognitive decline,” and “retirement AND cognitive functi*.” Included were peer-reviewed studies with participants close to retirement or retired, using a longitudinal design, and including retirement operationalizations (e.g., age at retirement and time spent in retirement) and cognition as outcome variables. We focused only on occupational retirement. Studies on other kinds of retirements (e.g., from sports), of pathology-related cognitive decline, using qualitative methods, and non-empirical works (e.g., comments) were excluded.

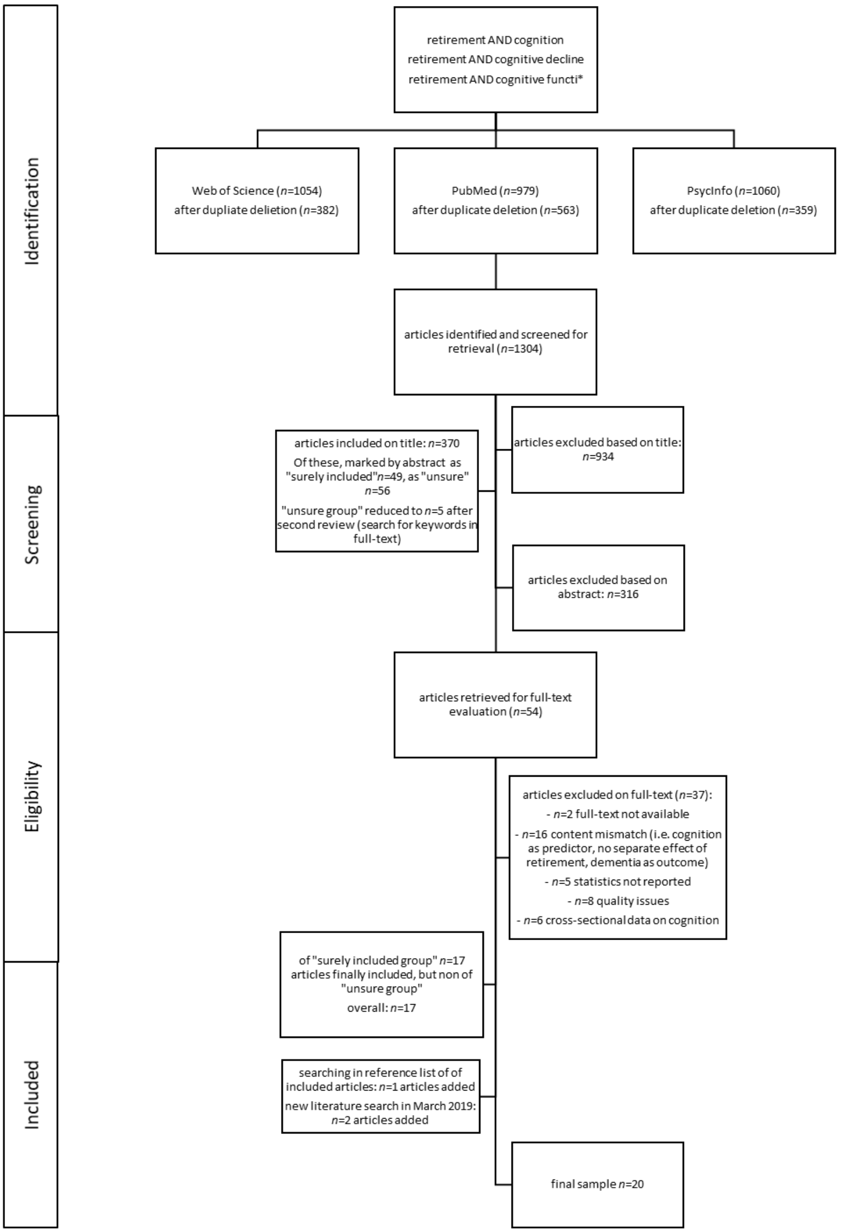
Identification of Relevant Studies

The studies were evaluated using several steps (see flowchart in Figure 1). A comprehensive full-text review was conducted for 54 articles, of which 17 were eventually included in the published review. Ambiguities concerning the inclusion and coding of the individual studies were discussed with the second author (IH). All reference lists from the finally included articles were searched for additional relevant articles, leading to the identification of one further appropriate article. We then conducted an additional literature search on articles published after the first search to complete and update the literature list. Two further articles were then included in the overall sample, which finally consisted of 20 articles.

Quality Assessment

The quality assessment of the included studies was based on an adapted version of the Newcastle-Ottawa Scale (NOS; Wells, 2001) and the checklist of Meng et al. (2017). The studies were assessed based on 14 factors: reporting of important information (e.g., sample size); representativeness and generalizability of the sample; and measurement and outcome variables (e.g., retirement definition, cognition measurements, control of confounders, and follow-ups). A further key objective was to capture whether the studies considered and controlled for different biases (i.e., attrition/dropout, retest effects, and selection into retirement) that could influence the interpretability and generalizability of the results. For most aspects, 1 or 0 points were assigned, though partial points (0.5) were assigned for some. The sum of all points for each study was divided by the total number of questions examined, leading to a quality range between 0 and 1. In line with Meng et al. (2017), quality was defined as very low (0–0.35 points), low (0.4–0.59), medium (0.6–0.79), or high (0.8–1).

Figure 1. Flowchart of the review process.



Results

Study Characteristics

Most studies were categorized as of moderate (*n* = 12) or high quality (*n* = 7). Furthermore, most of the studies used U.S. Health and Retirement Study (HRS) data (*n* = 9), followed by data from the Survey of Health, Ageing and Retirement in Europe (SHARE, *n* = 3) and the U.K. Whitehall II study (*n* = 2). Other databases were used only once. Sample sizes were generally large and varied between 462 and 18,542 participants.

Retirement was mostly operationalized using self-reported retirement status (*n* = 11) or time spent in retirement (*n* = 10). Age at retirement was examined only in two studies. Four other studies applied spline models (Marsh & Cormier, 2001) with retirement as the pivot point. These studies modeled cognitive trajectories before and after retirement.

Different analytical approaches were observed in the 20 studies. Six studies conducted group comparisons using longitudinal data: they compared the cognitive trajectories of people who were working or retired for the whole study period with those of people who retired during the same period. Studies with a stronger focus on within-person changes used either a fixed-effects model in panel-structured data (Bell, Fairbrother, & Jones, 2018) or spline models.

The cognitive ability investigated in most studies was episodic memory (*n* = 14), followed by executive functions (*n* = 6) and cognitive composite scores (*n* = 6). Verbal fluency (*n* = 4), spatial abilities (*n* = 1), and numeracy (*n* = 1) were less often examined. The only crystallized ability considered was verbal fluency; all other abilities were fluid.

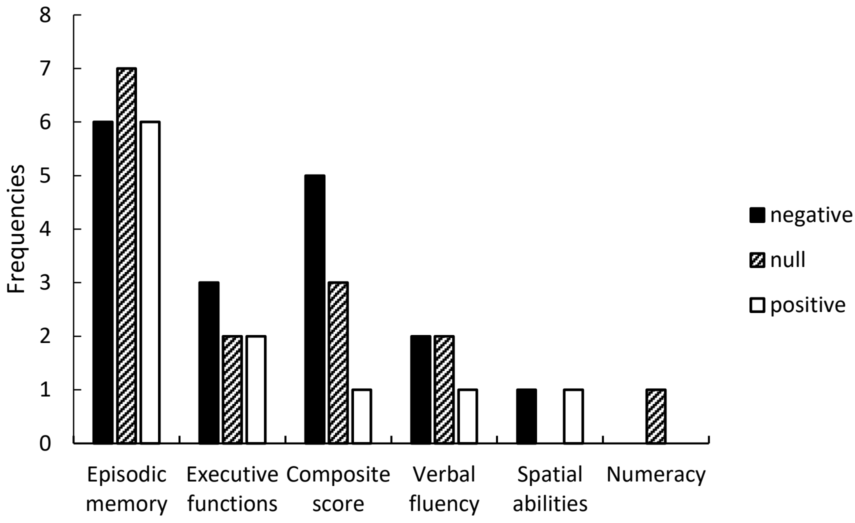
Synthesis of Findings Regarding Retirement and Cognition

The effects concerning the relationship between retirement and cognition are reported as positive, negative, or null depending on the direction and whether significance (alpha-level: .05) was reached. Some studies reported more than one finding (e.g., when different cognitive abilities were examined).

Overall, 15 studies reported negative, eight null, and nine positive associations between any retirement operationalization and any cognitive ability.

A closer look into the findings for specific cognitive abilities (Figure 2) did not reveal a clear trend for any of the abilities. Also, considering the different study settings, operationalizations of retirement events, and analytical approaches, the evidence was mixed.

Figure 2. Summary of findings from studies evaluating the association between retirement and different cognitive abilities.



Synthesis of Findings in Relation to Prior Occupational Demands

In relation to prior occupational demands, we identified three different trends. For retirees from physically demanding or blue-collar occupations, we observed a vague positive trend of retirement. Three studies reported positive effects while applying different retirement operationalizations and examining different cognitive abilities.

For retirees from cognitively demanding or white-collar jobs, two opposite trends were found. While two studies reported a negative relationship between retirement and cognition, three studies described positive associations between different retirement operationalizations and cognition.

Effect Sizes

Because the analytical approaches and variables used in the 20 studies varied substantially, a quantitative synthesis of the results was not possible.

In most studies the reported effects, even when significant, were relatively small. This applied to the overall effects of retirement as well as the effects of occupational demands on cognitive functioning (Clouston & Denier, 2017; Coe et al., 2012; Fisher et al., 2014; Lei & Liu, 2018; Roberts et al., 2011). However, not all studies commented on or interpreted the effects in terms of their magnitude.

Overview of the HEARTS Study used in Studies II to IV

HEARTS (Lindwall et al., 2017) is a longitudinal, population-based survey conducted annually that examines the psychological aspects of the retirement transition. Participants either had not yet retired, were in the process of retiring, or had already retired. It includes questions on sociodemographic background, working life and retirement, health and lifestyle, psychological factors such as well-being and personality, and cognitive tests.

In the spring of 2015, a representative national sample of 14,900 people aged 60 to 66 was invited to participate. Of those, 5913 (39.4%) completed the first wave (T1). Table 1 gives an overview of descriptive statistics of the sample per measurement wave. By default, the survey was conducted online; however, after a second reminder, a paper version, excluding the cognitive measures, was provided. Around 68.8% to 79.7% of those invited participated in the online version. The online sample consisted of slightly higher educated, male individuals, who were in better health and more often still working than the paper sample (Kelfve, Kivi, Johansson, & Lindwall, 2020).

Table 1. *Descriptive statistics of the HEARTS sample at each measurement wave.*

	N	Age (years) (SD)	Sex (% female)	Education (years) (SD)	Participation rate of T1 (%)
T1	5913	63.1 (2.0)	52.9	13.4 (3.5)	
T2	4651	64.1 (2.0)	53.9	13.6 (3.5)	78.7
T3	4320	65.1 (2.0)	53.4	13.6 (3.5)	73.1
T4	4033	66.1 (2.0)	53.2	13.6 (3.5)	68.2
T5	3935	67.1 (2.0)	53.7	13.7 (3.4)	66.5
T6	3914	68.1 (2.0)	53.3	13.7 (3.5)	66.2

Study II

Aims and Research Questions

For **Study II**, we followed up on some of the findings of **Study I**. In particular, we were interested in the interaction between retiring from jobs with varying occupational demands and engagement in cognitive leisure activities. In the literature review, we found positive effects of retirement for retirees from blue-collar jobs and both positive and negative effects of retirement from cognitively demanding and white-collar jobs. The positive effects of retirement on cognitive function were hypothesized to be mainly due to increased engagement in leisure activities after retirement boosting cognitive function in both blue- and white-collar workers (Fisher et al., 2014; Kajitani, Sakata, & McKenzie, 2017; Lei & Liu, 2018; Mazzonna & Peracchi, 2017). Furthermore, the loss of daily cognitive stimulation after retirement may increase the importance of engaging in cognitively stimulating leisure activities.

In line with this, one study found that a negative association between retirement and cognition could be attenuated by greater engagement in mental activities (Lee, Chi, & Palinkas, 2018). Another study found positive effects on cognition for post-retirement engagement in cognitive and physical leisure activities, which were independent of the effects of prior work complexity (Andel et al., 2016). However, in the latter study, leisure activity engagement before retirement was not considered. Therefore, it remains unclear whether changes or increases in engagement in cognitively demanding leisure activities can counter age-related cognitive decline after retirement and whether increased cognitive engagement can substitute for the loss of cognitive work demands.

The aim of **Study II** was therefore to investigate the interplay between pre-retirement occupational demands and cognitively demanding leisure activity engagement before and after retirement and their relationships to post-retirement cognitive functioning.

In the context of the notion of environmental complexity (Schooler, 1984), the use-it-or-lose-it hypothesis (Salthouse, 2006), and previous findings (see Zulka et al., 2019), we tested the following hypotheses: 1) *higher pre-retirement cognitive work demands are associated with more favorable post-retirement memory development*; 2) *increases in cognitive leisure over the retirement transition are related to more favorable post-retirement memory development*; and 3) *the positive effects of increases in cognitive leisure are more pronounced among retirees from low cognitively demanding jobs* given that those retirees had less stimulation in their jobs and could gain more from increased leisure engagement after retirement.

Study-Specific Methods

Sample

For **Study II**, we used HEARTS data from T1 to T5. In the presented analyses, we included participants who completed the memory test in at least one of the first five waves of the HEARTS measurements (*n* = 4749). To monitor the time when participants retired, we included only participants who participated in all waves, provided data on the retirement variable, and were not on sick leave or unemployed at the time of the data collection. Participants who did not fulfill these criteria were excluded from the analyses (*n* = 2351). Furthermore, participants who returned to work after retirement (*n* = 120) or for whom we did not have any pre- and post-retirement measurements, i.e., participants who were retired (*n* = 531) or working throughout the whole study period (*n* = 945), were excluded from the analyses. Furthermore, because information on leisure activity engagement was missing at T5, we could not calculate a difference score for cognitive leisure activity engagement for participants retiring between T4 and T5. We therefore excluded those participants from our analytic sample (*n* = 171). The final sample consisted of 631 participants. Occasionally missing values of time-constant covariates led to occasional decreases in the sample size, so that the sample size for the final growth curve model was *n* = 593.

Measurements

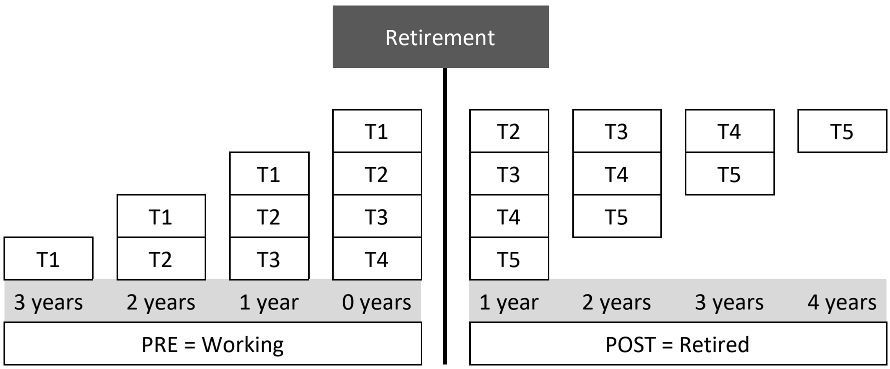
Retirement

Based on the question "To what extent do you currently work?" we categorized participants into working and retired participants. We restructured each participant's measurements such that they centered on the individual retirement event (see Figure 3).

Cognition

We measured memory using Thurstone's Picture Memory task, which consisted of 20 pictures that were subsequently presented to the participants for five seconds each (encoding phase). Directly after this phase, participants were asked to identify each of the 20 previously viewed pictures when they were shown together with three other related pictures (i.e., of the same or a similar object in a different position) that had not previously been shown (Thurstone & Thurstone, 1949). The memory test was conducted at T1, T2, T4, and T5.

Figure 3. Restructuring of time metric depending on the retirement event.



Work Demands

We used self-reported measures of cognitive work demands on the last measurement occasion before retirement. A personal mean score was created based on four items of the modified Copenhagen Psychosocial Questionnaire (Pejtersen et al., 2010).

Leisure Activity

The frequency of participation in seven cognitively stimulating leisure activities was asked before and after retirement. These activities included for example reading books or playing games. We calculated a personal mean for all pre-retirement answers and a second personal mean for all post-retirement answers and deducted the first from the second to obtain a difference score.

Covariates

We included two health indices, one for mental health and one for cardiovascular health. We also controlled for sex, years of education, retirement age, extent of pre-retirement work, perceived stress, and physical leisure activities.

Statistical Analyses

To model participants' memory trajectories before and after retirement, we used a two-slopes piecewise multilevel growth curve model (see, e.g., Raudenbush & Bryk, 2002). We restructured the individual's measurements as conditioned on the wave in which the participants reported their retirement. The first slope was derived from measurements before retirement and the second slope was derived from measurements after retirement. The model was centered such that the intercept fell on the pivot point, or at the first measurement in retirement. For all computations, we used the lmer function as part of the lme4 package (version 1.1-19) in R version 3.5.1, using restricted maximum likelihood (REML) estimation. We modeled the memory trajectories as a function of several time-constant covariates, including work demands, difference scores for cognitive leisure activity engagement, health, sex, education, retirement age, and work extent. Work demands, difference scores for cognitive leisure activity engagement, perceived stress, education, and retirement age were all mean centered. Sex was coded 0 for male and 1 for female. Health was centered on 0, indicating no diseases and work extent on "working full-time" before retirement. Our final models included random intercept and random pre- and post-retirement slopes. We specified the time-constant covariates of work demands and the difference score for cognitive leisure activity engagement so as to interact with the post-retirement slope, as well as a three-way interaction between work demands, the difference score for cognitive leisure activity engagement, and the post-retirement slope, while controlling for the effects of the mentioned covariates.

In a first step, we added a random effect for each participant, characterizing the individual variation from the intercept in each of the two models. Subsequently, the pre- and post-retirement slopes were added as individual fixed and/or random effects, separately or together in one model. We then tested for relevant individual differences in the slopes. Adding the post-retirement slope as random and fixed effects and the pre-retirement slope as a fixed effect gave the best model fit. Stepwise, we added cognitive work demands, differences in cognitively demanding leisure activities, and their interaction with the post-retirement slope. Finally, we tested a three-way interaction between the difference score for cognitive leisure activity, cognitive work demands, and the post-retirement slope to examine whether the post-retirement cognitive trajectories varied with different levels of work demands and/or changes in leisure engagement.

Results

We observed a small significant positive estimate of the pre-retirement slope, indicating a gain in cognition before retirement. The post-retirement slopes for memory were also positive and slightly greater than the pre-retirement slopes, suggesting further memory gains after retirement. However, the difference between slopes was small and not significant, indicating that the increase in memory did not accelerate over the retirement transition.

Cognitive Work Demands

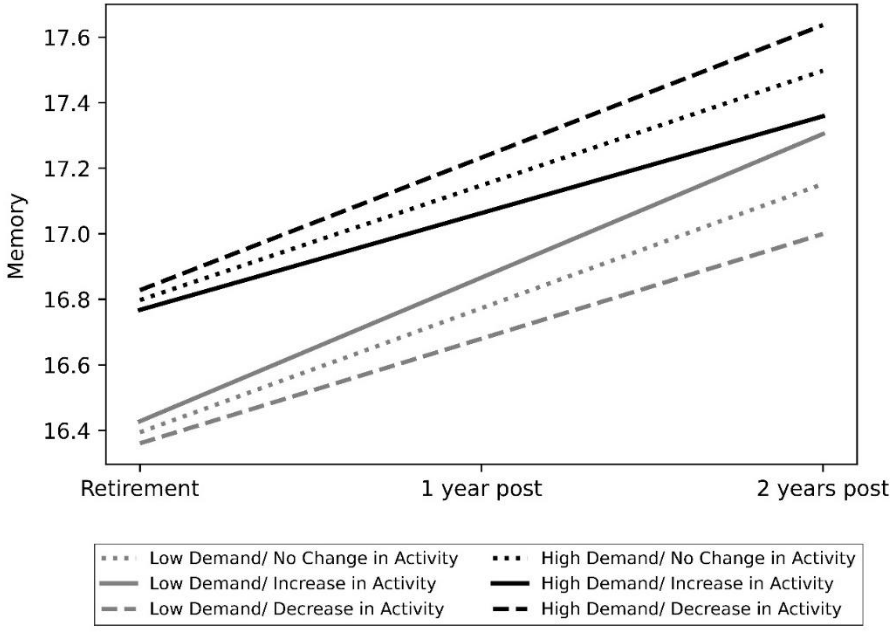
The estimate of the main effect of prior cognitive work demand was positive and significant, implying that, given a mean change in cognitively stimulating leisure activities, higher demand was associated with better memory performance at the time of retirement. Effects of the interaction of cognitive work demands with post-retirement slopes were small and non-significant, implying that cognitive change after retirement was independent of prior cognitive work demands (Hypothesis 1).

Differences in Leisure Activity Engagement

Changes in cognitively stimulating leisure activities over the retirement transition were associated with neither levels of memory at retirement nor with post-retirement changes (Hypothesis 2), given mean previous cognitive work demands.

However, when considering the interplay (i.e., three-way interaction) between prior work demands, changes in cognitively stimulating leisure activity, and post-retirement changes in memory (Hypothesis 3), we found that retirees from less cognitively demanding work had a greater increase in post-retirement memory when they increased their cognitively stimulating leisure activity. This effect was absent (and in fact tended in the opposite direction) among retirees from highly cognitively demanding jobs (see Figure 4).

Figure 4. Estimated changes in memory after retirement as conditioned on different levels of cognitive work demands and changes in cognitively demanding leisure activity engagement.



Note. High or low cognitive demands, respectively, refer to one standard deviation (SD) above or below the mean. Increase or decrease in cognitive leisure activity refers as well to one SD above or below the mean.

Study III

Aims and Research Questions

The aim of **Study III** was to examine personality traits in relation to the level of and change in reasoning ability in participants at retirement age. Because preparatory analyses did not indicate any change in reasoning ability in relation to the retirement event, we decided to use time in the study instead of the time to- and from the retirement event as the time metric.

Personality may be of specific interest for cognitive functioning in the years around retirement, because specific personality traits may help to ease or impede adjustment to retirement from work, which in turn may relate to changes in cognitive functioning (i.e., reasoning ability). More specifically, based on prior literature, we assumed we would find *a positive association between level of openness and level of reasoning ability, a negative association between level of conscientiousness and change in reasoning ability, as well as negative associations between level of neuroticism and the level of and change in reasoning ability*. Analyses of the associations between the levels of extraversion and agreeableness and the level of and change in reasoning ability were of an exploratory character, as derived from the discrepancies in the literature.

Study-Specific Methods

Sample

For **Study III**, we used HEARTS data from T1, and from T3 to T5. The reasoning ability measure used in this study was available from T2 to T5, so the first time point at which both reasoning ability and personality were measured together was at T3. To avoid a time lag between the cognition and personality measurements, we limited the data presented in this study to T3 to T5. To clarify, we used personality measurements from T3, and reasoning ability measurements from T3 to T5. Participants were excluded from the analyses if they did not participate in at least one cognitive measurement in the observation period of the study. The analyzed sample consisted of 3851 participants.

Measurements

Cognition

Logical reasoning ability was examined using a short version of Raven's Advanced Progressive Matrices (Arthur & Day, 1994). With a total time limit of three minutes, 12 different matrices were displayed. The matrices consisted of visual geometric designs with a missing piece. Participants were given six to eight choices to choose from and were asked to fill in the missing piece. The number of correct answers was used as the outcome variable.

Personality

The five factors of personality (i.e., Big Five) were measured using the Mini-IPIP scale (Donnellan, Oswald, Baird, & Lucas, 2006), consisting of a short version of the International Personality Item Pool. Each of the five subscales consisted of four items as measures of the respective personality traits: openness, conscientiousness, extraversion, agreeableness, and neuroticism. Ratings were given on a five-point scale, ranging from “Strongly disagree” (1) to “Strongly agree” (5). Coding for item numbers 6 to 10 and 15 to 20 was reversed.

Covariates

We controlled for sex, years of education, and age.

Statistical Analyses

We evaluated the associations between the personality traits and levels and change in reasoning ability using a latent growth curve model (LGCM) within the framework of a larger structural equation model (SEM). All estimates were derived using the maximum likelihood function as implemented in the lavaan R package (version 0.6-7). As part of this model, we included a measurement model for the personality traits (i.e., including five factors: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism). Factor loadings and intercepts for the first scale items associated with each trait were fixed to one and zero, respectively (except for the Openness factor, where we used the fourth item instead of the first, because the first item had the lowest bivariate correlations with the other items). In the growth part of the model, we investigated the mean level and linear change in reasoning ability over the three measurement points and fixed the factor loadings for the change component in ascending order starting with zero (i.e., 0, 1, 2). We used education, sex, and age, measured at T1, as covariates in the analyses. Both age and education were mean centered. The intercept (cognitive level) and slope (cognitive change) factors of the latent growth model were regressed on the five personality trait factors while controlling for the covariates.

Results

Higher level of extraversion ($\beta = -0.09$), conscientiousness ($\beta = -0.17$), and neuroticism ($\beta = -0.16$) were associated with lower level of reasoning ability. Furthermore, higher levels of openness were related to higher levels of reasoning ability (β = 0.16). Levels of agreeableness was not related to levels of reasoning ability (p = .301).

On average there was an increase in reasoning ability over time (0.01, SE = 0.23) and relatively small variability in the change component (0.02, SE = 0.04). None of the personality traits was, however, associated with the rate of linear change (p > .05).

The overall model fit of the final model in this study was rather poor ($\chi^2(274)$ = 3459.947, CFI = .794; TLI = .758; SRMR = .056; RMSEA = .055, 90% CI[.054, .057]); however, in line with studies applying similar personality scales.

Additional Results

In additional analyses, we evaluated whether changes in the five personality traits across T3, T4, and T5 were related to levels of and changes in reasoning ability in separate models, controlling for age, education, and gender. We tested for measurement invariance in personality over time defined as a ≤−0.010 change in the comparative fit index (CFI) supplemented by a ≤.015 change in the root mean square error of approximation (RMSEA; Chen, 2007).

We established time invariance (Meredith, 1993) for the agreeableness and conscientiousness models by constraining the factor loadings (ΔCFI < 0.007, ΔRMSEA < .002), scalar time invariance for the neuroticism model by additionally constraining the intercepts (ΔCFI < 0.007, ΔRMSEA < .003), and strict time invariance for the extraversion model by additionally constraining the residuals (ΔCFI = 0.001, ΔRMSEA = .002). For openness, we did not establish measurement invariance over time. The results of the associations between change in the five personality traits and change in reasoning ability did not give any indication of relationships over time (see Table 2).

Table 2. *Associations between change in reasoning ability and change in the Big Five personality traits over three years.*

Parameter		Estimate	*SE*	*p*	95% CI *LL*	95% CI *UL*	β
Change in Reasoning Ability							
1	Extraversion Level	0.01	0.02	0.63	-0.03	0.05	0.08
	Extraversion Change	-0.13	0.16	0.42	-0.44	0.19	-0.24
	Age	0.00	0.01	0.73	-0.01	0.02	0.06
	Education	0.00	0.01	0.80	-0.01	0.01	-0.04
	Gender	0.05	0.03	0.10	-0.01	0.12	0.27
2	Agreeableness Level	0.04	0.07	0.54	-0.09	0.17	0.19
	Agreeableness Change	-0.23	1.21	0.85	-2.62	2.16	-0.21
	Age	0.00	0.01	0.81	-0.02	0.03	0.07
	Education	0.00	0.01	0.81	-0.02	0.01	-0.07
	Gender	0.05	0.05	0.39	-0.06	0.15	0.24
3	Conscientiousness Level	0.02	0.03	0.54	-0.05	0.09	0.14
	Conscientiousness Change	-0.26	1.11	0.81	-2.45	1.92	-0.25
	Age	0.00	0.01	0.71	-0.01	0.02	0.06
	Education	0.00	0.01	0.84	-0.01	0.01	-0.03
	Gender	0.05	0.03	0.12	-0.01	0.11	0.24
4	Neuroticism Level	-0.02	0.04	0.67	-0.10	0.06	-0.12
	Neuroticism Change	0.29	1.11	0.80	-1.89	2.47	0.36
	Age	0.00	0.01	0.83	-0.02	0.03	0.05
	Education	0.00	0.01	0.87	-0.02	0.01	-0.04
	Gender	0.06	0.05	0.27	-0.04	0.16	0.25
5	Openness Level	-0.02	0.05	0.64	-0.12	0.07	-0.11
	Openness Change	-0.23	1.42	0.87	-3.00	2.55	-0.11
	Age	0.00	0.01	0.95	-0.02	0.02	-0.01
	Education	0.00	0.01	0.71	-0.01	0.01	0.05
	Gender	0.06	0.03	0.05	0.00	0.13	0.25

Note. SE = standard error; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Study IV

Aims and Research Questions

To investigate the second main research question of this thesis, that is whether IQ determined early in life, is related to life satisfaction over the retirement transition and how it relates to social resources, we designed **Study IV**.

In particular, we tested the following hypotheses. First, we hypothesized that *higher IQ in young adulthood is associated with higher levels of life satisfaction before retirement (H1).* We thereby referred to the assumption that advantages in mental ability determined in early life may unfold their positive effects when there is a need to adapt to changes related to growing older. These advantages may include greater availability of coping strategies and/or greater well-being promoting working and retirement arrangements that are more likely among individuals with higher initial IQ (Bain et al., 2003; Dingemans & Henkens, 2014; Heybroek et al., 2015).

Second, we assumed that *increases in life satisfaction over the retirement transition are associated with increases in social contacts with friends, but not with family or neighbors (H2).* Our hypothesis referred to prior studies showing that social relations promote life satisfaction in retirement (Goldberg et al., 2008; Price & Balaswamy, 2009; Topa et al., 2017) and evidence suggesting that, specifically, contact with friends, rather than with family or neighbors may be of special importance for life satisfaction (Kail & Carr, 2019).

Third, we hypothesized that *IQ in young adulthood moderates the association between changes in life satisfaction over the retirement transition and changes in social contacts with friends (H3).* We expected that lower initial IQ combined with receding or stable friendship contacts would be associated with the least positive development in life satisfaction, while high initial IQ and increasing friendship contacts over the retirement transition would be associated with the most positive such development. Moreover, the latter group of individuals with higher initial IQ were hypothesized to have access to a wider range of coping strategies gained over their life-span, making them more independent of the strategy of increasing social contacts. Even if they experience stagnant or receding social contacts, these individuals may observe more positive life satisfaction development comparable to that of those with lower initial IQ and a widening network of friends.

Study-Specific Methods

Sample

For **Study IV**, we used HEARTS data from T1 to T6. Participants were included if data were available for them on the cognitive tests conducted during military conscription (*n* = 1722). To examine possible changes in life satisfaction in a period when the individual retirement transition occurred, we further restricted the sample to participants who were not retired at T1 (*n* = 131) and retired in any of the following five waves. The analyzed sample consisted of 924 men.

Measurements

Life Satisfaction

We measured life satisfaction from T1 to T6 using the Satisfaction With Life Scale (Diener, Emmons, Larsen, & Griffin, 1985). The scale consisted of five items (e.g., "I am satisfied with my life"). Answers were rated on a seven-point scale, ranging from strongly disagree (1) to strongly agree (7).

Social Contact

Based on three items from the Lubben Social Network Scale-18 (Lubben & Gironda, 2003, 2004), social contacts were assessed. These involved how often the participants saw or heard from a) the relative (outside their household) with whom they have the most contact, b) the neighbor with whom they have the most contact, and c) the friend with whom they have the most contact. Answers ranged from (1) once a year or less, (2) a few times a year, (3) once a month, (4) once a week, (5) some times a week, to (6) daily.

Cognition in Conscription Data

The conscript examination involved four different cognitive tests (Carlstedt, 2000). These were: (1) *Instructions*, involving following verbal instructions; (2) *Concept Discrimination*, marking one word not matching four others; (3) *Paper Form Board*, judging which set of disarranged parts (out of four sets) would result in a target object when rearranged; and (4) *Technical Comprehension*, solving technical and physical problems.

Retirement

The question "Are you retired (i.e., have started to receive old-age pension)?" was used to categorize participants as either "working" or "retired" on each measurement occasion.

Covariates

We controlled for years of education, retirement age, and two health indices, one for mental health and one for cardiovascular health.

Statistical Analyses

To examine our research questions, we applied a latent growth curve model (LGCM) within the framework of a larger structural equation model (SEM). We used the full maximum likelihood function as implemented in the lavaan R package (version 0.6-7) to derive all estimates. The first part of the model included developing an adequate measurement model for the six measures of life satisfaction. We therefore generated a six-latent-factor confirmatory model based on the item scores at each wave, while fixing factor loadings and intercepts for the first item to one and zero, respectively. Following the model specification in Hansson et al. (2017) and based on thematic similarities, we added bivariate correlations between items 1 and 3 (i.e., thematic focus on present) and between 4 and 5 (i.e., thematic focus on past). We evaluated measurement invariance over time defined as a ≤ -0.010 change in comparative fit index (CFI) supplemented by a $\leq .015$ change in root mean square error of approximation (RMSEA) (Chen, 2007). The six latent factors were then included in the growth part of the model, in which we investigated the mean level and linear change in life satisfaction over the six measurement points by generating one latent intercept (i.e., LS intercept) and one latent slope factor (i.e., LS slope). Factor loadings for the change component were fixed in ascending order starting with zero (i.e., 0, 1, 2, 3, 4, 5). We further added correlations between the same items over time. We additionally specified a confirmatory one-factor model for the four cognitive sub-tests from conscription data (i.e., the IQ-factor), fixing the factor loading and intercept of the first sub-test to one and zero, respectively.

For each of the three different social contacts (i.e., friends, family, and neighbors), we calculated parallel models, in which we included two growth factors, one for level of (i.e., SC intercept) and one for change in (i.e., SC slope) social contacts in a similar manner (i.e., fixing the factor loadings for slope in ascending order starting with zero), respectively. Because none of the participants was retired at T1, the latent intercepts can be interpreted as measurements before retirement.

To investigate our first hypothesis, the latent LS intercept was regressed on the latent IQ-factor while controlling for the effects of education, cardiovascular and psychological symptoms, retirement age, as well as the latent SC intercept. The second hypothesis was examined by regressing the latent LS slope on the latent SC slope, while controlling for education, cardiovascular and psychological symptoms, retirement age, and the IQ-factor. To evaluate whether the hypothesized effect occurred only for contact with friends or also for contact with family and neighbors, we calculated three parallel models. We decided to consider the types of social contact in separate models to limit the complexity of the total model. To investigate the third hypothesis, we additionally included in the models an interaction term between the latent IQ-factor and latent SC slope regressing on the latent LS slope. Retirement age, education, social contact were mean centered, whereas cardiovascular and psychological symptoms were centered on zero (i.e., no symptoms). All cognitive tests were *z*-transformed.

Results

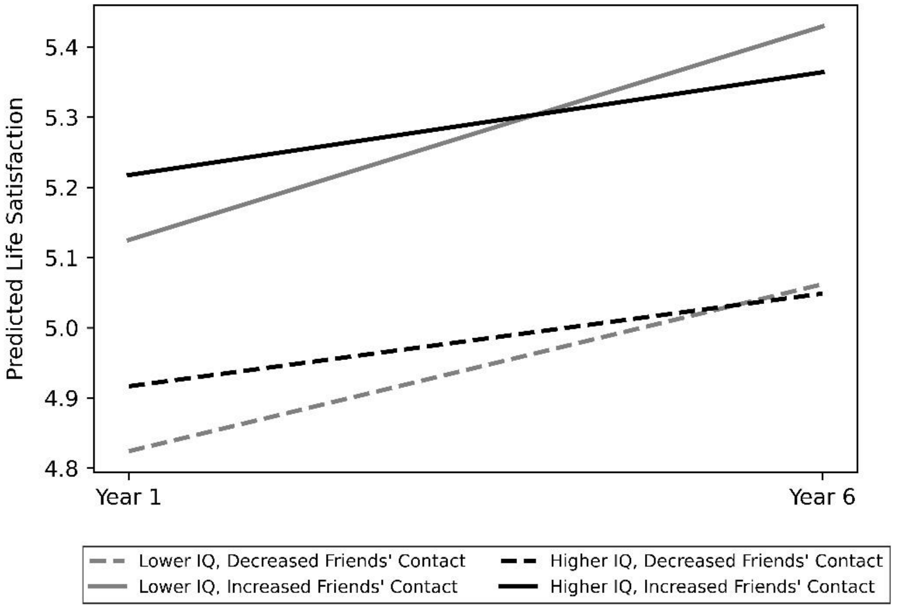
Independent of IQ and change in friendship contacts, we observed an overall significant increase in life satisfaction over the retirement transition (friend contact model: $\beta = 0.261$, family contact model: $\beta = 0.256$, neighbor contact model: $\beta = 0.252$).

Contrary to our expectations concerning the first hypothesis (H1), IQ in young adulthood was not associated with level of life satisfaction before retirement (friend contact model: $p = 0.187$, family contact model: $p = 0.454$, neighbor contact model: $p = 0.440$) in any of the three models.

However, we found support for the second hypothesis (H2), namely increases in life satisfaction over the retirement transitions were related to increases in contact with friends ($p < 0.05$), but not to increases in contact with family or neighbors. This finding was also emphasized by the relatively large effect sizes in the friend contact model ($\beta = 0.30$) versus the smaller effect sizes in the other social contact models (family contact: $\beta = 0.04$, neighbor contact: $\beta = 0.03$).

In accordance with our third hypothesis (H3), we found an interaction effect between IQ in young adulthood and change in contact with friends, but not between IQ in young adulthood and change in contact with family or neighbors. However, the pattern we observed was contrary to our expectations. For individuals with higher initial IQ, we found that the gains in life satisfaction were much more weakly associated with changes in friend contact than for individuals with lower initial IQ. For those with lower initial IQ, increasing friend contact was related to the highest observed gains in life satisfaction, while stagnant to receding friend contact was associated with substantially smaller gains. When considering predicted overall life satisfaction levels after retirement, individuals with increased friend contact exhibited the highest values, especially in those individuals with lower initial IQ. For decreasing friend contact, this pattern was repeated: individuals with lower initial IQ exhibited higher life satisfaction levels after retirement than did those with higher initial IQ (see Figure 5).

Figure 5. Estimated changes in life satisfaction over the retirement transition as conditioned on different levels of initial IQ in young adulthood and changes in contact with friends.



Note. Higher or lower IQ, respectively, refer to one standard deviation (SD) above or below the mean. Increased or decreased friends' contact refer as well to one SD above or below the mean.

GENERAL DISCUSSION

This thesis addressed two overall research questions: (1) *Does retirement influence cognitive functioning and, if so, what factors may affect this relationship?* and (2) *Is IQ, as determined early in life, related to life satisfaction over the retirement transition and how does it relate to social resources?*. Below, I discuss the results of the four studies that were the basis of this thesis. In doing so, I refer to prior literature and theories in the field of cognitive aging and retirement. I then review the strengths and potential limitations of the included studies. In addition, I discuss implications for theory, research practice, and social policy, as well as ethical considerations, and research gaps. I conclude with some general remarks.

Cognitive Aging and Retirement

One overall aim of this thesis was to investigate the relationship between cognitive aging and retirement and to answer the question as to whether retirement has an impact of cognitive functioning. Another aim was to test the role of factors identified in the literature to be of potential interest in the association between retirement and cognition: occupational background, leisure activity, and personality. In **Study I**, we conducted a systematic literature review to obtain a comprehensive overview of the current state in the field. Based on the findings of **Study I**, we designed **Study II**, an empirical study of memory change over the retirement transition, in which the impacts of work demands and cognitively demanding leisure activity were examined. In **Study III**, we studied personality in relation to reasoning ability changes in individuals at retirement age.

The literature review in **Study I** revealed overall mixed findings regarding the association between retirement and cognition, even when considering different cognitive abilities. Positive, null, and negative associations between retirement and cognition were found. We found no clear pattern of changes in fluid abilities, which are known to be more sensitive to the aging process and to various conditions (e.g., stress; Shields, Sazma, McCullough, & Yonelinas, 2017) potentially accompanying the retirement transition. The evidence for crystallized abilities was also conflicting; however, only a few studies examined crystallized abilities, which could have resulted in less reliable findings. Variations in study characteristics (i.e., study quality, operationalizations of retirement, and analytical approaches) could not explain the conflicting results. It therefore remained unclear whether the retirement event adds to the normal aging-related cognitive changes.

Studies II and **III** found increases in memory over the retirement transition and increases in reasoning ability in the years around retirement. These findings may imply that retirement does not negatively affect memory, which is partly in line with two prior studies using a similar analytical approach as that used in **Study II**. Both studies observed a less steep decline in episodic memory after versus before retirement (Andel et al., 2015; Fisher et al., 2014). Another study, however, reported a decline in verbal memory over the retirement transition in British civil servants (Xue et al., 2017). In that study, verbal memory was assessed using a free recall test, whereas in our study, memory was assessed using a less sensitive recognition test. Because age-related differences in recall memory are greater than age-related differences in recognition memory (Danckert & Craik, 2013), it is not surprising that Xue et al. found a decline in memory, while we found gains (reflecting practice effects and learning). Furthermore, Xue et al. focused on civil servants and had a longer observation period of up to 14 years before and after retirement, while HEARTS (at the time of the analyses) was a population-based study with a maximum follow-up of four years before and after retirement. It may therefore be hypothesized that the short- and long-term effects of retirement on memory might differ from each other.

The increase in reasoning ability in individuals in the same age range as the HEARTS sample is furthermore in line with longitudinal studies showing less pronounced cognitive declines (or even increases, i.e., learning) than those found in cross-sectional studies (Rönnlund et al., 2008; Rönnlund & Nilsson, 2006; Schaie, 1996). However, because we used the same versions of the cognitive tasks in relatively short time intervals (i.e., one year), practice effects likely occurred. To independently interpret time (i.e., aging) and practice effects, it is necessary to separate age and birth cohort effects (see, e.g., Hoffman, Hofer, & Sliwinski, 2011). Because our study design and data collection did not allow the sufficient separation of these effects, the change in memory and reasoning ability over time should be interpreted as a combination of aging and practice gains. The findings of **Studies I** to **III** are elaborated on in the following sections.

Work Demands

Although the literature review in **Study I** revealed mixed results, the findings were clearer for crystallized abilities: no post-retirement change was found in relation to previous occupational experiences (Opdebeeck, Martyr, & Clare, 2016). These findings are in line with previous findings on the relationship between cognitive reserve indicators and crystallized abilities. For example, different levels of education (as an indicator of cognitive reserve) were not related to different trajectories in crystallized abilities in normal aging (Christensen et al., 2001).

For fluid cognitive abilities, the review revealed mixed findings. The only relatively conclusive pattern was related to occupation. Blue-collar workers showed a vaguely positive trend in terms of improved cognitive functioning post retirement, while for white-collar workers or retirees from cognitively demanding jobs, the evidence concerning fluid abilities after retirement was mixed, and both negative and positive results were found.

Studies that found a positive trend in cognition following retirement from blue-collar jobs explained this in relation to the use-it-or-lose-it hypothesis and underlined the relevance of leisure activity engagement (Coe et al., 2012; Lei & Liu, 2018; Mazzonna & Peracchi, 2017). Cognitive stimulation at the job was discussed as the main factor. Blue-collar jobs may not offer as much cognitive stimulation as do white-collar jobs. Retirement, in turn, could increase available time for cognitively stimulating activities, which retirees, especially from blue-collar jobs, would likely benefit from.

The negative trend for cognition in retirees from white-collar jobs was also explained by the use-it-or-lose-it hypothesis (Finkel et al., 2009; Xue et al., 2017). The reduction in cognitive stimulation after retirement might be especially high for retirees from more cognitively stimulating jobs, so this decrease in stimulation could negatively affect cognitive functioning after retirement. However, the authors of those studies emphasized that other psychological factors such as social roles within the working life or attachment to the job could be especially important in jobs that involve high complexity or higher positions. Retiring from those jobs might cause a psychological burden or distress that could at least partially explain the cognitive decline after retirement (Wilson et al., 2006).

The positive trend of improved cognition after retirement from white-collar jobs was likewise discussed in terms of the use-it-or-lose-it hypothesis. Again, engagement in leisure activity was seen to be the key mechanism behind these effects. Retirees from white-collar jobs may have the (financial) resources and motivation to engage in (cognitively) stimulating leisure activities, which in turn could be beneficial to cognitive functioning after retirement (Fisher et al., 2014; Kajitani et al., 2017). Consistent with the concept of cognitive reserve, substantial control over and responsibilities at work may have promoted people’s development of various behavioral strategies that could be applied when handling the consequences of cognitive decline (Andel et al., 2016).

In **Study II**, we found higher levels of memory for individuals who retired from more cognitively demanding jobs, which is consistent with the literature (Then et al., 2014). We furthermore tested for an association between cognitive work demands and changes in memory over the retirement transition, and found no supporting evidence. The findings of **Study II** were therefore not fully in line with the trends indicated by **Study I**. However, two studies in the literature review also found no associations between cognition, retirement, and occupational background. One study reported no systematic relationship between retirement length and different cognitive outcomes for white-collar workers (Coe et al., 2012). Another found no pre- to post-retirement change in verbal memory for retirees from clerical/support jobs (Xue et al., 2017). Thus, the results related to occupation in **Study II** do not necessarily confirm the results of **Study I**. However, considering the idea of cognitive reserve, findings such as ours may challenge claims derived from that hypothesis about moderation of the onset of age-related cognitive decline (Lövdén, Fratiglioni, Glymour, Lindenberger, & Tucker-Drob, 2020; for further discussion, see section *Implications – Theory*).

Leisure Activity Engagement

To investigate the hypothesized influence of leisure activity engagement on post-retirement memory and its possible relationship to different cognitive work demands, we examined changes in cognitively demanding leisure activity engagement in **Study II**.

Our results indicated no association between pre- to post-retirement changes in cognitively demanding leisure activities and memory trajectories over the retirement transition. This was not in line with previously reported positive effects of leisure activity engagement on post-retirement cognitive functioning (Andel et al., 2016). This could again be because Andel et al. investigated a period of up to 23 years after retirement (average 14 years), while our study had only a four-year post-retirement follow-up. Furthermore, differences in the measures of both the included leisure activities and the cognitive outcomes could have contributed to the conflicting results across studies. Additionally, Andel et al. focused on post-retirement leisure activity participation, whereas we examined change in engagement. Because Andel et al. did not find any effects of social leisure activities on cognitive aging trajectories, we did not control for them in our analyses. However, this may add additional value to future analyses, because a social component of activity engagement has been shown to contribute to positive effects on cognition in old age (Litwin & Stoeckel, 2016). Furthermore, Andel et al. used a composite score of three different subtests (i.e., Digit Span, Picture Memory, and Names & Faces) to assess memory, while we focused on only one memory sub-domain. Different facets of the same cognitive domain may have different post-retirement trajectories, a possibility future researchers may wish to examine. Because the evidence from previous studies concerning the association between leisure activity and cognitive aging is inconclusive (Gow et al., 2014;

Litwin et al., 2017), future research is needed, particularly regarding retirement.

Concerning the hypothesized positive effect of maintaining cognitive stimulation after retirement by engaging in cognitively demanding leisure activity in dependence of prior work demands, we examined the interplay between cognitive work demands, changes in cognitively stimulating leisure activity, and post-retirement memory changes.

The results revealed that for individuals with relatively lower levels of cognitive work demand, an increase in cognitively demanding leisure activities after retirement was related to an increase in memory after retirement. This finding suggests that especially individuals who had little daily cognitive stimulation at work may have the greatest benefit from increasing cognitively stimulating leisure activities after retirement. Specifically, the increased engagement may improve their memory functioning (Kajitani et al., 2017; Lei & Liu, 2018; Mazzonna & Peracchi, 2017).

Similar effects for individuals with more highly cognitively stimulating jobs were not observed, possibly because they were already sufficiently stimulated through their work and did not additionally benefit from stimulation through cognitive leisure activities. The model estimates instead suggested that among retirees from highly cognitively demanding jobs, increases in activity were related to less memory gain after retirement, which was surprising and difficult to explain. However, this finding could in part relate to the fact that larger ceiling effects occurred in the post-retirement memory measurements for the group of retirees from highly cognitively demanding jobs who increased their activity engagement to a greater extent than for other participants.

It is also conceivable that individuals retiring from less cognitively demanding jobs might have started to engage in more novel activities than did individuals from higher cognitively demanding jobs. This may be an important aspect to consider, because novelty in tasks and activities has been shown to stimulate adaptive changes in cognition relevant to promoting brain health (Fissler, Küster, Schlee, & Kolassa, 2013; Fritsch, Smyth, Debanne, Petot, & Friedland, 2005). In line with that, positive effects on cognitive aging were found in participants who began to engage in cognitively stimulating leisure activities (Litwin et al., 2017).

Personality

In **Study III**, we investigated the relationship between level of and change in reasoning ability and personality. Our results revealed that higher levels of openness were associated with better reasoning, which is in line with previous studies (e.g., Austin et al., 2002; Chapman et al., 2012). The suggested link between openness and better cognitive functioning may be explained by more engagement in different leisure activities among individuals scoring high on that trait (Jackson et al., 2020; Stephan et al., 2014), which in turn could stimulate cognitive functioning. Even though Soubelet and Salthouse (2010) did not find any mediation effects of leisure activity engagement on the association between openness and cognition, more research is needed to firmly address that question. That we observed changes in cognitively demanding leisure activities specifically over the retirement transition in **Study II** opens up an interesting opportunity for future studies of whether these changes were related to level of or changes in personality, and in turn to cognitive functioning.

We furthermore found that higher levels of neuroticism were associated with lower levels of reasoning ability, but not with change in reasoning ability. However, our results can still be considered in line with the chronic stress hypothesis, which suggests that chronic stress – more prevalent among individuals scoring higher on neuroticism – can cause permanent neuronal damage and in turn may impair cognitive functioning (e.g., Lupien et al., 2009; Sapolsky et al., 1986). However, with our study design, we were not able to investigate any causal relationships. Furthermore, the rather short follow-up could have contributed to our not finding any association between level of neuroticism and change in reasoning ability, which has been observed before (Chapman et al., 2012; Hock et al., 2014; Wilson et al., 2003).

Concerning extraversion, we found that higher levels of extraversion were associated with lower levels of reasoning ability, which may be partly explained by possible external distractions caused by the online data collection approach of the HEARTS study. The test performance of individuals scoring high on extraversion may have been particularly impaired, as they have a tendency to seek more external stimulation, possibly distracting them from the cognitive task (Chapman et al., 2012). This is also in line with studies showing that individuals scoring high on extraversion have greater difficulties in online teaching situations (Varela, Cater, & Michel, 2012; Yu, 2021) and tend to respond more carelessly in online surveys (Ward, Meade, Allred, Pappalardo, & Stoughton, 2017).

Furthermore, higher levels of conscientiousness were related to lower levels of reasoning ability, although previous studies mainly report no association between these variables. Yet, it is conceivable that individuals with lower cognitive abilities might develop a tendency towards more conscientious behavior to compensate for their lower abilities. In contrast, individuals with higher cognitive abilities may be less dependent on being formally organized and persistent to reach their desired goals (Chamorro-Premuzic & Furnham, 2004). However, we did not find any association between changes in reasoning ability and changes in conscientiousness, which again may be due to the relatively short follow-up period employed in this study. It is furthermore possible that the described mechanism may have already manifested before retirement age, so no change-change associations were observed.

Concerning agreeableness, we did not find any association with level of or change in reasoning ability, which is what we expected based on a missing conceptual foundation for the specific link between cognition and agreeableness (Curtis et al., 2015).

Overall, changes in none of the five personality traits were related to changes in reasoning ability at retirement age. Again, the short observational period could have contributed to our not observing any relationships. Additionally, with our study design, we did not directly test the effect of retirement on personality changes, which could be of interest in future studies, because personality changes may occur in response to handling developmental tasks potentially related to retiring (Hutteman et al., 2014).

Generally, studying work demands, leisure activities, and personality in relation to cognitive aging in the retirement transition or at retirement age gave new insights that helped us disentangle their complex interaction. While **Studies II** and **III** examined work demands and leisure activities, and personality separately, it should also be considered that these three factors could interact with one another in a complex way (see, e.g., Kandler & Piepenburg, 2020) and with additional factors not included in both studies (for further discussion, see the section *Research Gaps and Future Directions*).

Concerning the three constructs and their value in explaining the mechanisms underlying cognitive aging, personality as applied in **Study III** rather helped to classify and distinguish individuals and their probable behaviors, whereas leisure activity engagement and work demands may have given important hints concerning general underlying mechanisms such as the importance of enduring cognitive stimulation.

All three factors are, furthermore, aspects that are somewhat modifiable and thereby have the potential to positively affect cognitive developments. However, personality seems to have a stronger genetic component, making actively changing it more difficult (e.g., Sanchez-Roige, Gray, MacKillop, Chen, & Palmer, 2018). In contrast, work demands, and especially leisure activity engagement may have greater potential to be altered in the short-term, which in turn may positively affect the cognitive aging trajectories of older adults.

Considering a life-span perspective, based on the evidence of **Studies II** and **III**, it remains unclear at what point in the life-span certain levels of personality traits or work demands are more or less beneficial for cognitive functioning in older age. However, we showed that changes in cognitively demanding leisure activities were relevant over the retirement transition (depending on prior work demands).

IQ in Young Adulthood, Social Contact, and Retirement Adjustment

The second main research question concerned the role of IQ as determined in early adulthood in retirement adjustment and how IQ moderates the association between social contacts and life satisfaction over the retirement transition, which we investigated in **Study IV**.

The results of this study do not support the first hypothesis of a positive association between higher initial IQ and higher life satisfaction levels before retirement. We found that there was no significant link between an individual's young adulthood IQ and the level of life satisfaction in any of the three models (i.e., friend, family, and neighbor contact models). Overall, life satisfaction in the retirement transition appeared to be weakly related to initial IQ levels, with only a small main positive effect of initial IQ on life satisfaction (which was similarly reported by Bain et al., 2003). Thus, it appears that good cognitive functioning in early adulthood does not directly act as a resource for those needing to adapt to changes in anticipation of retirement. Gow et al. (2005) suggested that higher initial IQ may lead to either increased or decreased life satisfaction, possibly explaining why the main effect observed by us was small and not significant. While higher IQ may mean better resources (e.g., favorable employment) and thus higher life satisfaction, accompanying higher awareness of the potential downsides of retirement (e.g., receding social contact) as well as of personal shortcomings in respect to aging may lead to lower well-being (Diener, 1984; Kail & Carr, 2019). The latter may be related to the negative association between higher initial IQ and changes in life satisfaction that we additionally observed in all three models. That finding may also be explained by the possibility that individuals with lower IQ may experience a relief from less favorable working conditions, promoting their life satisfaction after retirement (Wang, 2007). In relation to the resource-based dynamic model (Wang et al., 2011), which assumes that changes in resources are the driving force of changes in well-being over the retirement transition, it is also conceivable that cognitive change rather than IQ levels are related to changes in life satisfaction.

Regarding our second hypothesis about the relationship between changing social contacts and changing life satisfaction during the retirement transition, our expectation was that increased friend contact would be related to increases in life satisfaction, while contact with family and neighbors would have no such relationship. In line with earlier studies (Fiori et al., 2006; Kail & Carr, 2019), we found empirical support for this second hypothesis, leading to the suggestion that investing in social contacts with friends while transitioning into retirement leads to greater life satisfaction. Regarding the overall trend, however, we observed stability in all three types of social contacts over the retirement transition, but with large differences between individuals. This finding suggests that for some individuals, leaving the working context may reduce social interactions, which is especially interesting considering that our sample consisted solely of men due to lack of conscription data on women. Relatedly, one prior study suggested that men reduce their social contact after leaving their work context, while women do the opposite (Huang & Yang, 2013).

Our third hypothesis was intended to probe a potential moderating effect of young adulthood IQ on the relationship between life satisfaction and changed social contact over the retirement transition. Our results supported this hypothesis, and we discovered that only the interaction between changes in friend contact and initial IQ was significant. However, while we expected that individuals with low initial IQ and receding friend contact would show the least positive development in life satisfaction, the observed direction of the interaction was somewhat contrary to our expectations. We expected higher initial IQ to balance the effect of decreasing friend contact, leading to life satisfaction changes similar to those of individuals with lower initial IQ and increasing friend contact. Our results indicated, however, that the latter group of individuals showed the most increases in life satisfaction. Among those with decreased friend contact, those with lower versus higher initial IQ showed larger increases in life satisfaction as well. Also when looking at the level of life satisfaction after retirement, we observed that individuals with lower initial IQ and increased friend contact showed the highest value, followed by those with a higher initial intelligence and increased friend contact.

These findings can be interpreted in various ways. First, that prior studies observed an association between lower initial IQ and lower income and occupational level (Furnham & Cheng, 2016; Irwing & Lynn, 2006; Lager et al., 2017; Strenze, 2007) may mean that those individuals mostly entered jobs with less control and higher job strain, both of which in turn have been related to lower life satisfaction (Stansfeld, Shipley, Head, Fuhrer, & Kivimaki, 2013). To counteract this negative effect, these individuals may be more actively investing in contact with friends outside of work. Leaving the job context then allows the pursuit of friendship contacts to an even greater degree, possibly explaining the large positive effect on well-being seen among this group. Second, the well-being of individuals with higher initial IQ may not improve markedly with increased social contacts, because other factors such as working and retirement arrangements (e.g., greater financial security or bridge employment) affect their well-being to a greater extent (Dingemans & Henkens, 2014; Heybroek et al., 2015). Following the self-determination theory (Ryan & Deci, 2000), which suggests autonomy and competence as basic psychological needs next to connectedness (i.e., contact with e.g., friends), individuals with higher initial IQ may be less reliant on contact with friends, as they are more likely to fulfill their autonomy and competence needs in their occupation. In contrast, individuals with lower initial IQ may be less likely to find satisfying occupations, so social contacts may become more important for their well-being. Consequently, individuals with higher initial IQ may benefit less from an increase in friend contact, as this psychological need is of overall less importance for them than for those with lower initial IQ. The aspect of increased importance of autonomy for individuals with higher IQ may also be mirrored by the observation that these individuals are more likely to retire early (Iveson & Deary, 2019), i.e., by autonomous decision. Third, increasing contact with friends could also represent an active coping strategy for dealing with changes related to retiring. However, this strategy could be comparatively less important for people with higher initial IQ as they may have a wider range of possible coping strategies to choose from. One such strategy could involve enhanced problem-solving skills more accessible to individuals with higher initial IQ. This is because they may have trained and developed their problem-solving skills over their life-span, having spent more time in more complex environments (e.g., occupations; Strenze, 2007). In contrast, for people with a smaller range of coping strategies (i.e., lower initial IQ) increases in social contacts could have a more positive effect. Because we did not investigate other coping strategies in this study, future studies need to evaluate whether this hypothesis finds support.

Strengths and Limitations

Overall, this thesis aimed at answering two main research questions making use of the advantageous combination of different methodological approaches. Addressing the first research question by obtaining a systematic overview of the existing literature in the field (**Study I**) helped us identify relevant research gaps that were then examined in the following studies (**Studies II** and **III**). Applying the overarching theoretical perspective of life-span development furthermore allowed us to study cognitive aging and retirement from different angles. Cognitive abilities (i.e., changes in memory and reasoning ability and IQ in young adulthood) thereby served as both the outcomes of interest and an explanatory variable, enabling a more overarching understanding of the complex interaction between cognition and retirement. Furthermore, the individual studies had important strengths and limitations that I discuss below.

A clear strength of the literature review (**Study I**) was its broad inclusion criteria, which enabled us to include studies with different cognitive outcomes and different study characteristics (i.e., cognitive outcomes, study designs, and analytical approaches). This broadness, however, made a quantitative synthesis of the results virtually impossible. We were, however, able to include more studies than did an earlier review of this topic (Meng et al., 2017) and to look at a different set of moderators that gave more evidence of the complexity of the relationship between retirement and cognition.

The fact that all the coding was conducted by the main author could be considered a limitation of the literature review, but we addressed this issue by discussing inclusion and coding uncertainties with the second author (IH). Furthermore, we developed clear protocols and instructions for study inclusion and coding before collecting the articles. Moreover, the first and second authors discussed all the results of the included studies and together extracted relevant information.

The updated and thorough literature search enabled us to find 20 eligible studies that provided a solid basis for examining the potential impact of retirement on cognition. Nevertheless, there remains the risk that we may have missed results of unpublished studies or other sources, and that could threaten the comprehensiveness of the extracted studies.

Studies II to **IV** used data from a large longitudinal population-based Swedish study that conducted annual follow-ups, which gave us the unique opportunity to study various aspects of cognition and the retirement transition. More concretely, the data structure applied in **Study II** allowed us to precisely monitor and follow up participants' experiences in the retirement transition with pre- as well as post-retirement data for all participants included in our models. Furthermore, by using a spline model with trajectories before and after retirement, we increased the chances of detecting potential changes in memory related to the retirement event itself.

The rather strict inclusion criteria used in **Study II** gave advantages as well as disadvantages. To control for working/retirement status throughout the whole study period, we included only participants who had consecutively participated in several waves. We chose this approach because we were interested in the effects of the loss of cognitive stimulation at work and its possible replacement with leisure engagement.

We furthermore focused on the traditional retirement transition (i.e., participants who changed their retirement status once they retired were excluded). Including participants who returned to work could have produced interesting insights into differential effects of varying retirement paths on cognitive functioning, but it would have increased the already high complexity of the statistical models. By restricting our sample to participants with no missing data, we may also have decreased the representativeness of the sample, making the results less generalizable. Because the online HEARTS participants who completed the cognitive tests were already better educated and in better health than those who completed the paper version of the survey (Kelfve et al., 2020), this bias was probably increased by including people who had participated in several consecutive waves. Using such a large population-based sample from across Sweden, however, may have boosted the representativeness of the sample and thereby increased the generalizability of the findings.

Based on the possible generalization difficulties due to the strict inclusion criteria in **Study II**, in **Study III**, we broadened the criteria and did not model cognitive trajectories in relation to the retirement event (i.e., in a spline model). Instead, we decided to investigate the general relationship between reasoning ability trajectories and personality in a sample at retirement age. Through this approach, we were not able to make a statement as to whether the retirement event as such was related to personality. However, because our own preliminary analyses indicated no change in reasoning ability in relation to the retirement event, we favored including more participants and not modelling reasoning ability change in relation to the retirement event. Working with a larger sample is especially advantageous when considering the rather small effect sizes found in previous studies of personality and cognitive functioning in older age, as well as the effect sizes found in **Study II**. **Study III** therefore allowed us to make more general conclusions about reasoning ability trajectories and personality in this sample of individuals around retirement age.

Challenges encountered in **Studies II** and **III** included our conducting cognitive measurements without control of the testing environment, i.e., using online measures. This means that we did not have information about whether participants were distracted while attempting the cognitive tasks. This, in turn, may have led to less reliable data. Not having participants come to the lab for testing, however, had the advantages of allowing the HEARTS study to be conducted annually and of including a fairly large sample from across Sweden. Annual follow-ups are especially valuable when examining the short-term effects of a certain event using pre- and post-event measurements. By applying clear and pre-determined rules for data cleaning, we furthermore increased the reliability of the measurements.

Another issue concerns retest effects, in which test performance increases with repeated test administration (Thorvaldsson, 2015). These may have occurred in the HEARTS dataset, as the same test versions were used in each wave. Due to our study design and data collection we were not able to sufficiently separate age and birth cohort effects, which is necessary to independently interpret time and practice effects (see, e.g., Hoffman et al., 2011). Therefore, the cognitive changes detected in **Studies II** and **III** should be interpreted as a combination of aging and practice gains. Possible ways to deal with retest effects could have been to use parallel instead of identical test versions or to use numerical test contents, which are known to be less prone to retest effects (Scharfen, Peters, & Holling, 2018). However, establishing parallel test versions that equivalently measure cognitive abilities (e.g., with equal item difficulty) is challenging, yet necessary for unbiased within- and between-person comparisons (Gross et al., 2012; Lebedeva, Huang, & Koski, 2016).

Furthermore, we relied on self-reported data for the explanatory variables, i.e., concerning work demands, leisure activity engagement, personality, and all the covariates. Concerning work demands, we asked only about the last job before retirement. This could have distorted the picture of the demands faced throughout a participant's total working life. However, using objective measurements based on occupational classification systems may neglect personal perceptions of work demands, and these perceptions may differ between people sharing the same job title (Lazarus & Folkman, 1984).

The derived variable capturing leisure activity engagement contained information about the frequency of participation as well as the number of leisure activities. Using it, we sought to address some of the challenges of measuring activity engagement. First, it may be problematic to present only a limited selection of activities, which may neglect other activities participants usually engage in. Second, the measurement scale was rather broad, with the highest resolution set to "every day," which may not capture hourly increases in engagement. A combination of both the number of activities and the frequency of engagement may have given a more robust measure of activity engagement than using only one of these. However, because cognitive stimulation could be provided by a wide range of activities, we could still have missed activities with potential importance for cognitive functioning. This could have biased our results (Bielak, 2010). Future studies may benefit from extending the list of activities or using open-ended questionnaires to get a more comprehensive picture of participants' leisure activity engagement. Furthermore, because self-reports of leisure activity can be biased by recollection mistakes, for example, future studies could incorporate the reports of other observers (e.g., spouses, and fellow activity participants) or physiological measurements (e.g., obtained using activity trackers for physical activity) to supplement the self-reports (Bielak, 2010).

Concerning the personality measures in **Study III**, the rather poor model fit highlights that measuring personality is complex (Hopwood & Donnellan, 2010). Specifically, designing a personality trait inventory that works well in confirmatory factor analysis is difficult, and further research efforts may be needed to increase the validity of studies using the Mini-IPIP (and similar inventories). However, we decided to keep the trait structure, as the Mini-IPIP is a validated and common personality inventory (Donnellan et al., 2006), which in turn facilitates, for example, effect-size comparisons across studies.

The bias of self-selection into retirement may not have been completely ruled out in **Study II**. However, by excluding participants retiring from sick leave, we took into account retiring for health reasons. Furthermore, the mean retirement age in our sample was close to the actual retirement age in Sweden, suggesting that retirement probably occurred for normative instead of health reasons (OECD, 2019).

The short follow-up period used in **Studies II** and **III** may be seen as disadvantageous in comparison with other studies with longer follow-ups. However, for **Study II** this means that we avoided the difficulties of disentangling normal age-related cognitive changes from retirement-related effects, as may be necessary in studies of the long-term effects of retirement.

In **Study IV**, HEARTS data from six waves with consecutive measurements of the outcome of interest, i.e., life satisfaction, were available, so that no general time lags appeared between measurements– as apparent in, for example, the cognition measurements.

Besides being able to include one further wave of HEARTS data in **Study IV**, the linkage to conscription data allowed a unique perspective on life-span development. Specifically, being able to investigate the relationship between early life IQ and life satisfaction in the retirement transition in the same individuals around 40 years later gave novel insights and highlighting the importance of considering early life factors when studying outcomes in later life.

However, because only men had to undergo military conscription when they were 18 years old in cohorts the same age range as ours, conscription data are often only available for men. Therefore, the generalizability of our results to women is limited, specifically because gender differences in life satisfaction and social contacts have been observed (Calasanti, 1996; Kim & Moen, 2002). In particular, the results concerning social contacts may be specific to men (Huang & Yang, 2013), because women tend to have bigger social networks in later life than do men (McLaughlin, Vagenas, Pachana, Begum, & Dobson, 2010). However, more than 95% of all men attended conscription, so bigger selection effects among men should not be expected (Carlstedt, 2000).

Furthermore, the cognitive tests as part of the Swedish Enlistment Battery were conducted for the specific purpose of testing military suitability, even though being based on the idea of measuring the general intelligence factor, *g* (Carlstedt, 2000). Motivational aspects grounded in personal approval or objection to military service may have affected the test performance of some individuals.

Another aspect concerning the measures in **Study IV** relates to the fact that we only asked about contact with the closest friend, family member and neighbor. Individuals may engage in multiple contacts and thereby increase their number of social contacts after retirement, which was not possible to track with our data. However, following the idea of the socioemotional selectivity theory, especially older adults place greater emphasis on a few important social relationships rather than on multiple casual relationships (Carstensen, 1992). Therefore, our measure of social contact may still give a valid indication of the amount of contact in our sample. However, we were not able to include measures of the quality of these contacts, which has been shown to be more strongly associated with subjective well-being in older adults than qualitative measures of social contacts (Pinquart & Sörensen, 2000).

Implications

Based on the findings of this thesis, implications for theory, research practice, and social policy can be identified and will be discussed below.

Theory

This thesis was based on a life-span perspective on human development (Baltes, 1987; Baltes et al., 1980), and the results of the four included studies gave evidence of some of the underlying assumptions of this perspective.

One of the basic assumptions of the life-span perspective is that human development is characterized by changes in different domains over time. Indeed, in all three empirical studies (**Studies II** to **IV**), we observed changes in different domains over time, such as the cognitive (i.e., memory and reasoning ability), behavioral (i.e., leisure activity), psychological (i.e., life satisfaction), and social (i.e., social contacts) domains. We furthermore observed relevant interrelationships between these domains – another basic idea of life-span development – explaining some of the observed inter- and intra-individual differences in cognitive functioning and life satisfaction in older age.

In all studies included (although less so in **Study III**), we specifically examined one life event (i.e., retirement) that potentially influences individual development (Baltes & Willis, 1979). Concerning cognitive development, however, we found only limited evidence that the retirement event has a general effect on post-retirement short-term cognitive trajectories. As discussed before, the short follow-up in **Study II** could have contributed to our not finding any such effects. From the use-it-or-lose-it perspective, retirement poses a risk to post-retirement cognitive functioning, and overall negative effects of retirement should be expected. Yet, the review in **Study I** and the empirical results of **Study II** did not indicate any general negative effect of retirement on cognition. One could therefore question whether the event of retirement in fact affects cognitive functioning to any great extent.

Referring to the STAC-r (Park & Reuter-Lorenz, 2009), one of the prominent cognitive aging theories that directly relates to the idea of life-span development (see the section *Cognitive Aging Theories*), we primarily examined so-called life-course experiences. These experiences are assumed to provoke either neural enrichment or neural depletion, and in turn to affect the level and rate of cognitive change positively or negatively. In particular, neural enrichment factors that we investigated in **Studies II** and **III** included intellectual engagement (i.e., cognitively demanding leisure activities and work demands), education, physical leisure, and, potentially, personality traits such as openness (i.e., individuals more prone to engage in activities). Depletion factors comprised personality traits such as neuroticism as well as vascular diseases, perceived stress, and psychological diseases. While some of these factors were only included as control variables, others (i.e., cognitively demanding leisure activities, work demands, and personality) were investigated in relation to their interactions with cognitive change. The findings of **Studies II** and **III** generally support the idea that life-course factors may benefit (i.e., lower work demand and increased cognitively stimulating leisure activities) cognitive development or relationships to levels of cognitive functioning (e.g., positively to levels of openness, negatively to levels of neuroticism). However, with our study design, especially in **Study III**, we were not able to investigate any causal relationships, meaning that it remains unclear whether the enriching or depleting factors cause higher or lower levels of cognition. Furthermore, our data only allowed investigations on a behavioral level, meaning that we could not examine any assumptions concerning underlying neurobiological mechanisms. It therefore remains unclear whether exposure to enriching or depleting factors affects cognition by influencing compensatory scaffolding capacity. Future studies including brain-imaging data would be needed to probe the underlying assumptions of the STAC-r.

Supporters of the use-it-or-lose-it hypothesis assume leisure activity engagement to be an important substitute for cognitive stimulation at work in avoiding cognitive decline. Although we saw changes in leisure activity engagement over the retirement transition in **Study II**, these changes were in general not related to cognitive functioning after retirement. However, in interaction with prior cognitive work demands, cognitively demanding leisure activity engagement was shown to be relevant to post-retirement memory changes. Therefore, we must question whether the use-it-or-lose-it hypothesis, which assumes a general (immediate) decrease in cognition through a reduction in cognitive stimulation, is a valid framework for describing cognitive functioning in the retirement transition. Considering individual work circumstances may be a valid addition to the use-it-or-lose-it hypothesis. Furthermore, leisure activity may not be the only or most relevant factor in the interaction between retirement and cognitive functioning. Other factors relevant to post-retirement cognitive function may be job attachment, changes in social roles, and related psychological well-being (Finkel et al., 2009; Xue et al., 2017). Further development of the use-it-or-lose-it hypothesis could improve its value and applicability in the context of retirement and cognition. Such improvements, besides considering prior work demands, should include specifications for operationalizing activity engagement and its possible effects on different cognitive domains (Bielak, 2010; Salthouse, 2006).

Following the concept of cognitive reserve, occupational background may be of special importance to cognitive functioning after retirement. **Study I** gave some evidence that retirement may be beneficial for retirees from blue-collar or physically demanding jobs. However, in **Study II**, we found higher cognitive work demands to be related to higher levels of memory and no evidence for change in memory after retirement to be related to prior work demands. Again, **Study II**'s four-year follow-up after retirement may not be a suitable framework for studying the reserve-related effects of occupational backgrounds, which may become more important as cognitive decline starts to emerge. Longer follow-ups may be more relevant when pursuing cognitive-reserve hypotheses, which at the same time would entail the difficulties of disentangling age-related effects on cognition from retirement-related effects. Our study therefore instead supports evidence that cognitive reserve is more important in pathology-related cognitive changes than in age-related cognitive changes. This is because, higher reserves may buffer the negative effects of brain pathology, but not necessarily those of age-related cognitive changes (Boots et al., 2015; Lane et al., 2017; Lenehan et al., 2015; Xu et al., 2019; Xu, Yu, Tan, & Tan, 2015). As noted by Nilsson and Lövdén (2018), a distinct operational definition of cognitive reserve is still pending. To apply the concept of cognitive reserve in the context of retirement and cognition, this may be an inevitable next step.

Furthermore, our studies did not contribute evidence concerning the distinction between the concepts of cognitive reserve and brain maintenance because we were not able to include any neurobiological measures. To advance the development of a clearer distinction between these two concepts, it would be useful to investigate similar research questions as in **Studies II** and **III** in relation to neurobiological developments.

As mentioned, cognitive functioning in old age is known to be strongly related to genetics (Deary et al., 2012; Finkel et al., 2005). Incorporating genetics into the theoretical underpinnings when explaining the relationship between retirement and cognition may be another key to better understanding the underlying mechanisms of these relationships.

Concerning the resource-based dynamic model of retirement adaptation (Wang et al., 2011), **Study IV** gave supporting evidence for the idea that social resources facilitate retirement adaptation. Furthermore, our results were in agreement with the assumption that resources may interact with one another. Relating to IQ determined early in life, it could be debated whether cognitive change rather than IQ levels are more prognostic of changes in life satisfaction, which we did not examine in that study. This may apply, although the general intelligence factor has been reported to remain highly stable over the life-span (Deary, Whiteman, Starr, Whalley, & Fox, 2004; Rönnlund et al., 2015).

Overall, our study highlights that a life-span perspective on retirement adaptation is important to understanding changes in life satisfaction around the retirement transition. Although a life-span perspective is included in the resource-based dynamic model, it could be more greatly stressed that even resources measured relatively early in life could be related (through interactions with other resources) to retirement adaptation around 40 years later.

Research Practice

Some general remarks and advice for research practice arise from the observations and results specifically of the literature review.

Concerning more general biases in longitudinal studies of cognition, retest effects in many studies were handled by including a practice term in the statistical models indicating the number of assessments a participant took part in (e.g., Finkel et al., 2009). Thorvaldsson (2015), however, argued that this way of controlling for retest effects only holds if no cohort effects or selective attrition occurs, which is seldom a given. Applying parallel test versions or numerical test contents may be a more effective way to prevent retest effects (Scharfen et al., 2018).

Selective attrition as a threat to the generalizability of results (Baltes et al., 1971; Schaie et al., 1973) could be accounted for using advanced statistical techniques (e.g., growth-curve analyses or multiple imputations; see Asendorpf, van de Schoot, Denissen, & Hutteman, 2014).

Self-selection into retirement or reversed causality may be another aspect that should be addressed in studies of retirement and cognition. Econometric studies, for example, aim at finding a variable that is both correlated with retirement and only correlated with cognition through the effect of retirement, usually called an instrumental variable (Bonsang et al., 2012). An example of a typical instrumental variable is cross-country differences in early or statutory retirement age. Rohwedder and Willis (2010) proposed that most variations in early retirement decisions in cross-country comparisons depend on variations in public policies (e.g., differences in how profitable it is to work longer than the national early retirement age). The cross-country variation in early retirement age would then be correlated with the retirement decision, but would not be related directly to cognitive performance itself and would therefore be an appropriate instrumental variable (Rohwedder & Willis, 2010).

Overall, the different retirement definitions and operationalizations, as well as the different analytical approaches, hampered a systematic compilation of results in **Study I**. As described above, clear definitions and operationalizations that are instrumental in answering the research question posed are essential to the field. It therefore should be clear that it is the effect of the event of retirement that is being modeled, rather than comparisons among age-matched groups with different work or retirement experiences, who probably differ greatly from each other.

To systematize current scientific knowledge in a certain research field, it is important to pay attention to the origin of the data used. In the case of the present literature review, nine of the 20 studies were conducted using HRS data. Big and costly datasets provide significant benefits in terms of data quantity and sample size, but it may be important for the generalizability and reliability of the results to limit the usage of the same dataset for repeatedly answering very similar questions (Thompson, Wright, Bissett, & Poldrack, 2019). Similarly, knowledge of certain phenomena should not be based on only one relatively small sample. It was therefore positive to see other studies, including Asian studies, represented among the 20 included studies.

Considering the mixed evidence in **Study I**, efforts to engage in open science practices may be valuable in improving general research practice in the field of longitudinal secondary data analysis. With such changes, the likelihood of obtaining replicable research findings in the field of retirement and cognition may increase (Isaacowitz & Lind, 2019; Weston, Ritchie, Rohrer, & Przybylski, 2019).

Social Policy

As a consequence of the aging labor force, more people than ever will retire from work in the coming years and most people will spend a greater share of their lifetime in retirement than any previous generation (Tyers & Shi, 2007). Pension systems are therefore under pressure and improvements need to be made to them continuously (König & Sjögren Lindquist, 2016).

To address the challenges related to an aging society, one of the most prominently discussed ideas on a macro level (i.e., society and policy) is prolonging the working life of older adults. While remaining in the working force, individuals continue to pay their pension contributions, easing the financial pressure on pension systems. Furthermore, because a shortage of workers is projected to occur in the near future due to lower birth rates in younger generations and retirement of the baby boomer generation, retaining older workers in the labor force may be an adequate short-term solution (Walker, 2007). Retaining older individuals in the workforce as well as recruiting already retired individuals back to the workforce may also have advantages on the meso level, namely, from the employer's perspective (Cleveland & Maneotis, 2013). These advantages include older adults' greater professional experience and expertise in their working fields (Jex, Wang, & Zarubin, 2007).

However, the advantages and disadvantages of prolonging working life on the micro level, i.e., from the individual's perspective, also need to be taken into consideration. Often-cited advantages include the opportunity to remain in a socially and possibly mentally stimulating environment, which are related to higher both physical and mental well-being (Diener et al., 1999). Furthermore, being forced to leave the labor force despite wanting to continue to work is associated with lower retirement satisfaction (van Solinge & Henkens, 2008). However, not all individuals want to or can prolong their working life.

Taken together, **Studies I** and **II** did not support the assumption that retiring poses a general threat to cognitive functioning. However, the effects of retirement may differ depending on the jobs people retire from. Based on the results of **Studies I** and **II**, one may conclude that leaving a low cognitively stimulating environment can be beneficial for cognitive functioning, implying that continuation in low cognitively stimulating environments and physically demanding jobs to a higher age may be more disadvantageous cognitively than would retiring earlier. The positive general increase in life satisfaction observed in **Study IV** also highlights that most people's well-being benefits from retiring.

The results of this thesis highlight that it is of great importance to allow personalized retirement transitions. To individualize the retirement transition based on the individual's needs and wishes, aspects such as individual physical, psychological, and cognitive prerequisites, as well as work demands, may need to be considered. Strategies such as reduced work hours before retirement or bridge employment could be important tools with which to tailor retirement transitions (Beehr & Bowling, 2012). Because prolonging working life in relation to cognitive functioning and life satisfaction over the retirement transition was not a focus of this thesis, future research is needed before firm recommendations can be made.

To promote high life satisfaction after retirement, and thereby possibly prevent social isolation, loneliness and in turn poor mental and cognitive health in older age (Lara et al., 2019; Nicholson, 2012), **Study IV** furthermore implied that actively maintaining contacts with friends when retiring is important. This seems to apply specifically to individuals with lower initial IQ. Interventions such as low-threshold counselling for men at risk of social isolation aiming at increasing the contact with friends should already be in place before retirement. Such interventions could be organized publically or be recommended for employers to provide as part of individual retirement preparation. Future research needs to show whether similar recommendations should also apply to women.

Ethical Considerations

Ethical approval was given for HEARTS by Gothenburg's regional ethical board (Dnr: 970-14). Participation in the project was voluntary and participants were assured of their ability to exit the study at any time for any or no reason.

The data obtained were managed according to the General Data Protection Regulation (EU) 2016/679 of the European Parliament and according to the Swedish Public Access to Information and Secrecy Act (2009:400), both of which include regulations for safe data storage and processing. These regulations furthermore prevent the identification of any individual data point and thereby protect the personal rights of the participants.

HEARTS covered various topics, resulting in a comprehensive questionnaire. Completing the questionnaire could have been exhausting for some participants. However, participants could interrupt their participation at any time and resume later. Furthermore, participants were not in a laboratory situation in which they might feel more obliged to continue the testing.

After completing the questionnaire, participants were informed of the number of items they correctly answered in the cognitive tests. However, those numbers were not presented in relation to other participants' performances. Considering that participants might not expect such information when consenting to HEARTS and might feel stressed by it, we decided not to give any further personal feedback on the test results.

Research Gaps and Future Directions

Studies I to **IV** suggest some direction for future research. **Study I** highlighted specific aspects of study design, analytical approaches, and retirement operationalizations. Future research may benefit from modeling intra-individual changes and capturing retirement-related variations (e.g., using spline models). Furthermore, the development of a precise, domain-specific measure of cognitive functioning is vital, as often-used composite scores may obscure the contributions of individual domains.

A secondary aspect of our literature review that attracted our attention was the gender-specific occupational aspects of retirement and cognition. These were examined in some studies, but most reviewed studies included sex only as a control variable, so no clear conclusions about gender-specific patterns related to occupational factors could be drawn. In **Study II**, we furthermore observed higher levels of memory at retirement among women than men, which is in line with prior observations (McCarrey, An, Kitner-Triolo, Ferrucci, & Resnick, 2016). Future studies may want to incorporate gender-specific career experiences and gender-specific leisure activity patterns (Hassing, 2020; Jaumot-Pascual, Monteagudo, Kleiber, & Cuenca, 2018; Mayeda et al., 2020) in order to fully understand the relationship between retirement and cognition.

Focusing on other possible moderating factors such as job attachment as well as changes in social roles and in related psychological well-being may also be valuable (Finkel et al., 2009; Xue et al., 2017). Future research may also benefit from identifying sub-groups likely to decline in cognition after retirement in order to identify potential risk groups. In line with this, one study showed, for example, that besides gender, even motivational factors can explain intra-individual differences in cognitive decline after retirement. In that study, especially women who were high in goal disengagement experienced steep declines in episodic memory when retiring (Hamm, Heckhausen, Shane, & Lachman, 2020). One further aspect may be to consider different pathways to retirement, including different retirement circumstances, such as retiring from unemployment or sick leave (Carr et al., 2020). To further explore the association between work demands and retirement, including aspects of work-related stress (i.e., job strain) may be useful, because there is not yet consensus in the literature on whether retiring may be beneficial for the cognition of individuals experiencing high job strain before retirement (Andel et al., 2015; Nilsen et al., 2021).

One important factor that may influence the relationship between work demands, leisure activity engagement and post-retirement memory is novelty in tasks and activities, which could be crucial for stimulating adaptive changes in cognition and promoting brain health (Fissler et al., 2013; Fritsch et al., 2005). Supporting this view, positive effects on cognitive aging have been reported for participants who actively started to engage in leisure activities (Litwin et al., 2017) and for participants who experienced high novelty at work

(Oltmanns et al., 2017; Staudinger, Yu, & Cheng, 2020). In **Study II**, participants who retired from less cognitively demanding work may have started to engage in new activities to a greater extent than did retirees from higher cognitively demanding work, which may explain the findings regarding the third hypothesis in that study. With our data, we unfortunately had only limited insight into novelty experiences before and over the retirement transition of the participants. We nevertheless assessed the patterns of (dis)continuity in engagement after retirement (see Table 3). In our sample, most activities already being conducted before retirement, but about one quarter of the participants started to engage in one or more new cognitive and/or physical activities after retirement. This gives us the opportunity to examine the role of novelty in leisure activity engagement over the retirement transition in future studies.

Table 3. *Leisure activities and patterns of changes in engagement over the retirement transition.*

	No change, not done before	No change, done before	New post-retirement activity	Stopped with activity
Cultural Activities, %	4.5	89.4	3.1	3.1
Reading Books, %	5.8	89.5	2.3	2.4
Reading Newspapers, %	0.2	99.4	0.2	0.3
Playing Games, %	16.8	60.4	13.0	9.9
Using Computer, %	0.0	99.5	0.3	0.2
Solving Crossword Puzzels/ Sudoku, %	13.6	76.5	5.8	4.1
Participating in Evening Classes/ Study Groups, %	65.3	13.7	15.6	5.5

While we investigated work demands and leisure activities, and personality in separate studies, future studies may want to incorporate both into one study. Specifically, bidirectional links between leisure engagement and personality traits have been reported (Kandler & Piepenburg, 2020) and may give a more comprehensive picture of cognitive changes in the time around retirement. In particular, that we observed changes in cognitively demanding leisure activities specifically over the retirement transition in **Study II** opens up an interesting opportunity to investigate whether these changes were related to levels of or changes in personality traits, and, in turn, to cognitive functioning.

Because our study design in **Study III** did not directly allow any conclusions to be drawn about the effects of the retirement event itself, future studies may want to further investigate this topic, despite expected small effect sizes. In addition, because the data in **Study III** enabled only a restricted life-span perspective, future studies could profit from extending their observational period so as also to observe possible change-change relationships between cognition and personality. Furthermore, the studies may include additional cognitive domain trajectories and different birth cohorts.

Concerning **Study IV**, as discussed in the section *Strengths and Limitations,* the observed results may only generalize to men. Therefore, future studies using IQ data on women in early adulthood should be conducted to evaluate whether patterns similar to those observed here are also found in women. Because the sample size in **Study IV** was reduced substantially by focusing on participants for whom conscription data were available and who were not retired at T1, we were not able to investigate different pathways to retirement in our analyses, which could give interesting insights into individual adaptation to retirement (Hansson et al., 2017). Future studies may, for example, consider retirement from unemployment, the extent to which individuals worked before retirement, as well as whether participants continued to work to a lesser degree after their retirement. Additionally, we were not able to include measurements of the quality of social contacts, which has been shown to affect subjective well-being in older adults (Pinquart & Sörensen, 2000). Therefore, future studies may want to incorporate quality measures of social contacts, such as perceived trust or closeness within social contacts, when investigating the relationship to life satisfaction.

Overall, future studies may want to expand the knowledge of changes in life satisfaction over the retirement transition by investigating other possible coping strategies, such as physical activity, bridge employment, or reduced working hours. Besides the relationship investigated in **Study IV** (i.e., social and cognitive resources), the resource-based dynamic model of retirement adjustment (Wang et al., 2011) furthermore suggests possible relationships between leisure activity engagement, work demands, cognition, and well-being after retirement, which we did not consider in for example **Study II**. Therefore, future studies may want to explore other aspects incorporated in that model in greater depth.

Conclusions

This thesis aimed at answering two main research questions: (1) *Does retirement influence cognitive functioning and, if so, what factors may affect this relationship?* and (2) *Is IQ, as determined early in life, related to life satisfaction over the retirement transition and how does it relate to social resources?*

The first two studies in this thesis specifically investigated whether retirement affects cognition. In **Study I**, we presented a systematic review of current research on retirement and cognition. Overall, the evidence that retirement moderates normal aging-related cognitive changes was mixed, even considering different cognitive abilities, study qualities, and study characteristics. Although we were not able to disentangle the relationship between retirement and cognition, we could exclude some reasons for the scattered pattern of the studies' findings by investigating different moderators. The results of **Study II** revealed an average gain in memory over the retirement transition, which suggests that retirement per se does not generally have negative effects on memory development.

In **Studies II** and **III**, we investigated how inter- and intra-individual differences in psychological and lifestyle factors such as cognitive work demands, cognitively stimulating leisure activities, and personality affect cognitive functioning around retirement. **Study II** gave insights into increasing cognitive stimulation being specifically beneficial for post-retirement memory development among individuals who reported low previous cognitive work demands, insights that may be incorporated into public-health recommendations. This means that future retirees (especially in occupations with low cognitive demands) should be encouraged to maintain a cognitively active lifestyle to prepare for retirement in good cognitive health.

In **Study III,** we found that four of the five personality traits we investigated were associated with levels of reasoning ability, but that none was associated with changes in reasoning ability over a period of three years around retirement.

Overall, the results of **Studies I** to **III** imply that cognitive functioning in the years around retirement is associated with different possibly modifiable psychological and lifestyle factors that could potentially promote positive cognitive developments in older adults.

Concerning initial IQ and social contact as resources for successful retirement adaptation, the results of **Study IV** suggest that especially individuals with lower initial IQ seem to gain the most from actively maintaining contacts with friends when they retire. Interventions to support these individuals in increasing their contact with friends may be beneficial for their well-being.

While we did on average observe increases in well-being over the retirement transition even for those with decreasing social contacts, reduced social participation is generally related to isolation and loneliness. In an aging society, these problems are being observed more frequently and their consequences can be far-reaching, causing reduced well-being and negative health outcomes. Therefore, supportive interventions for at-risk individuals should be in place even before their retirement transition, to help provide them with beneficial social contact that can promote increased well-being over the retirement transition and prevent negative issues stemming from loneliness beyond retirement.

Finally, our results demonstrate that factors in early adulthood seem to interact with predictors of outcomes later in life. Conclusively, to better understand retirement adjustment it would be instructive to consider factors influencing development over the life-span and influencing resource availability in later life.

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APPENDIX

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Study I

Study II

Study III

Study IV