The Association Between Emotional Expressivity in Early Adulthood and Healthy Aging in Late Adulthood

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Canada's population is aging quickly, with growth in the population of older adults now exceeding that of younger adults. This increase emphasizes the need for research on healthy aging to determine potential predictors that may lead to improved aging outcomes. Healthy aging models and theories have incorporated various components, such as physical, cognitive and self-assessments of health, into the definitions of healthy aging. Emotions expressed in early adulthood may affect how well individuals age, given the strong associations found between emotional expressivity and longevity. Specifically, positive emotional expression has been linked with longevity. Although longevity may be indicative of an individual living a long, healthy life, it does not necessarily equate to healthy aging. Thus, determining if an association exists between emotional expressivity in early adulthood and healthy aging in late adulthood should be considered a priority given the current and future population demographics.

This research project aimed to assess this association using data from the Nun Study. The Nun Study is a longitudinal study of aging and health. It included 678 members from the School Sisters of Notre Dame who were 75 years of age or older at baseline. From archival records, a total of 180 autobiographies handwritten by the sisters in early adulthood (mean age = 22) were coded for emotional content (i.e., positive, negative, and neutral emotion words). The current study focused on the positive and negative emotion words and the overall combination of the two. The outcome of healthy aging was previously constructed using Nun Study data, and incorporates performance-based measures of cognitive and physical function and self-rated function. Healthy aging was assessed dichotomously and as four levels (i.e., excellent, very good, good, and not healthy aging). Analyses included descriptive analyses, such as univariate and bivariate statistics, as well as multivariable analyses using binomial and multinomial logistic

regression techniques, with an analytic sample of 149 participants. This research project aimed to strengthen current knowledge regarding emotions and healthy aging. Additionally, exploring the associations using a four-level healthy aging outcome provided an opportunity to examine a more detailed definition of healthy aging compared to typical dichotomous healthy aging definitions, to further clarify any significant findings.

Based on the descriptive and multivariable analyses, significant associations were found between overall and positive emotional expressivity and two-level healthy aging. Among those with a Master's degree or higher, participants aging well were approximately twenty times more likely to express high overall emotions (OR: 20.19, 95% CI: 2.09-681.26) or high positive emotions (OR: 19.54, 95% CI: 2.15-631.96) than those not aging well. In contrast, among those with a Bachelor's degree, no significant associations were found for overall or positive emotional expressivity and two-level healthy aging. Using the four-level healthy aging outcome, significant positive associations were found between high overall emotional expressivity and the 'excellent' level of healthy aging, compared to those not aging well, when no covariates were present, and in the models adjusted for *APOE*-ε4 and for idea density, but not for the fully adjusted model. Although not statistically significant, a pattern was found among the models using four-level healthy aging, whereby as the level of healthy aging moved from 'good' to 'excellent', the odds of expressing high overall and positive emotions increased. No significant associations were found between negative emotional expressivity and a lower likelihood of aging well when using either the two or four-level healthy aging measure. The findings from this research build off of the significant associations already known between emotional expressivity and longevity, and establish emotional expressivity as a possible predictor for healthy aging. By clarifying the role that emotions play towards aging well, individuals may be able to modify their emotions to

reflect more positive emotions, or less negative emotions. Additionally, creation of novel strategies or activities to maximize the expression of more positive emotions may lead to potentially healthier aging outcomes with benefits for both individuals and society.

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3MS	Modified Mini-Mental State Examination
ADLs	Activities of Daily Living
APOE	Apolipoprotein E
CI	Confidence Interval
CIHI	Canadian Institute for Health Information
EE	Emotional Expressivity
HA	Healthy Aging
HPA	Hypothalamic-Pituitary-Adrenal Axis
IADLs	Instrumental Activities of Daily Living
MMSE	Mini-Mental State Examination
OR	Odds Ratio
PANAS	Positive and Negative Affect Schedule
SD	Standard Deviation
UN	United Nations
WHO	World Health Organization

Chapter 1

Introduction

Population aging presents one of the most significant public policy challenges facing society today. Indeed, older people now constitute a larger portion of the population compared to any other time in history (Satariano, 2006). By 2050, it is projected that the world's population of individuals aged 60 years and older will approximate 2 billion (World Health Organization (WHO), 2015). Certainly, the pace of population aging around the world, including Canada, is increasing dramatically, which is raising concern (Canadian Institute for Health Information (CIHI), 2011; WHO, 2015). Specifically, Canada's health care system might be unable to handle the increasing health care needs of the aging population (CIHI, 2011). In 2010, approximately 14% of Canadians (4.8 million) were aged 65 years and older, and by 2036 this proportion is expected to rise to approximately 25% (10.4 million) (CIHI, 2011). Now more than ever, it is imperative that further aging research be conducted in order to ensure that those entering old age have the capability to age well.

Living a longer life brings numerous opportunities for older people and their families, as well as for society as a whole. If people have the chance to experience these additional years of life while aging well, and are living in a supportive environment, then they should be able to maintain their quality of life into old age. In contrast, if these extra years of life are dominated by substantial declines in physical and mental abilities, the consequences become more negative for the aging population and for society (WHO, 2015). Having a low probability of disease and disability, maintaining high cognitive and physical functional capacity, and being actively engaged with life, may all be representative of healthy aging (Rowe & Kahn, 1997). With the

changing demographics, age-related research regarding predictors of healthy aging should become a priority.

Emotion-related attitudes and states are part of a growing literature demonstrating that positive and negative emotions are associated with physical health, mental health, and longevity (Danner, Snowdon, & Friesen, 2001; Sin, Moskowitz, & Whooley, 2015; Steptoe, O'Donnell, Marmot, & Wardle, 2008). Currently, little is known about the influence of positive and negative emotions in early adulthood on healthy aging outcomes in late adulthood. Potential associations between emotions and healthy aging have not been explored, but instead research has focused on the relationship between emotions and longevity. Although living a long life may be indicative that an individual is in good health, longevity does not necessarily equate to healthy aging (Depp, Glatt & Jeste, 2007).

The present study aimed to strengthen current knowledge regarding emotions and healthy aging, and determine if an association exists between the two. The first aim of the study was to determine if overall (positive and negative) emotional expressivity in early adulthood was associated with healthy aging. The second and third aims explored positive and negative emotional expressivity separately to determine whether they were associated with a higher or lower likelihood of healthy aging, respectively.

In order to test these associations, secondary data from the Nun Study were used. The Nun Study is a longitudinal study of aging and health among members of the School Sisters of Notre Dame in the United States (Snowdon et al., 1996). All participants in this study agreed to a review of their archival (e.g., educational level) and medical records, cognitive (e.g., the Mini-Mental State Examination (MMSE)) and physical assessments (e.g., tests of activities of daily living (ADLs)) performed annually, and brain donation following death (Tyas, Snowdon,

Desrosiers, Riley, & Markesbery, 2007). A total of 180 autobiographies written between the ages of 18 and 32 were obtained from the archival records, and were previously coded for emotional expressivity (i.e., words classified by valence as positive, negative, or neutral), idea density, and grammatical complexity (Danner et al., 2001). A healthy aging measure has been defined and validated in the Nun Study (Tyas et al., 2007), and includes performance-based measures of cognitive and physical function (i.e., the MMSE, delayed word recall, ADLs, and instrumental activities of daily living (IADLs)), as well as self-rated function. Potential confounders and effect modifiers were taken into consideration as well (i.e., apolipoprotein E-ε4 (*APOE*-ε4), education, age at first cognitive assessment, age at the time the autobiography was written, idea density, and grammatical complexity). Overall, this research project explored the association between emotional expressivity and healthy aging.

The current research project comes at a time when the pace of population aging is growing considerably. Learning novel ways to maintain or improve healthy aging is therefore extremely important. A better understanding of the potential association between emotional expressivity and healthy aging will inform public health interventions that help promote healthy aging. Strategies could be developed to assess emotional expressivity in early adulthood which may then be used to help individuals learn more about their emotional expression. Individuals could then modify their emotions to reflect more positive emotions, or less negative emotions, thereby leading to potentially healthier aging outcomes. Additionally, the current findings could be very beneficial for facilitators of healthy aging, as novel strategies or activities could be developed to maximize the expression of more positive emotions, or fewer negative emotions, thereby potentially improving the health of individuals, and to a greater extent, the population as a whole, reducing the need for health-related care in older age.

Chapter 2

Literature Review

2.1 The Aging Population

In 2017, the world's population reached nearly 7.6 billion people, and is projected to increase to 8.6 billion by the year 2030 and 11.2 billion by 2100 (UN, 2017). Of the current global population, approximately 13% (962 million) are aged 60 or older (UN, 2017). Canada's population has experienced a large shift in the number of people aged 65 and older, with 2016 marking the first time there were more seniors 65 and older (5.9 million) than children 14 and younger (5.8 million) (Statistics Canada, 2017). From 2011 to 2016, the number of people aged 85 and older grew by 19.4%, which was nearly four times the rate for the overall Canadian population. During this same time period, centenarians grew by 41.3%, representing the fastest growing subgroup of the Canadian population (Statistics Canada, 2017). This shift in demographics from 2011 to 2016 was the largest observed since 1871, clearly reflecting that Canada's population is aging at a quick pace (Statistics Canada, 2017).

Currently, the life expectancy at birth in Canada is 80 years among men and 84 years among women, with more Canadians living to the age of 85 or older than ever before (Statistics Canada, 2017). Clearly, these statistics reflect the increase in life expectancy in Canada, and with this increase there is a greater need expected for health-related and social care.

A significant proportion of those who are aged 85 or older have activity limitations (Statistics Canada, 2017), which can be measured by assessing ADLs and IADLs. ADLs include measures such as bathing, dressing, or feeding, while IADLs include measures such as food preparation, telephone use, or taking medications. An individual may be considered aging well if they are able to complete most of these tasks, thus preserving their independence. In contrast, if

someone is unable, or has difficulty completing these tasks, their quality of life may be hindered, their level of independence may drastically decline, they may require help from other people or mechanical devices, and lastly, a higher degree of medical care may be needed.

The Canadian Institute for Health Information (CIHI) released a report estimating that a total of $228.1 billion was spent on health care in 2016, or roughly $6,299 per Canadian (Barua, Palacios, & Emes, 2017). One of the reasons behind this grossly large number is population aging. Typically, as the population continues to grow, the demand for health care services and expenditures increases concomitantly, and health expenditure data have consistently shown that older Canadians consume a greater number of health care dollars compared to middle-aged and younger Canadians (Barua et al., 2017). In fact, according to the most recent data on age-specific health spending collected in 2014, Canadians aged 65 and older consumed almost 46% of all public-sector health care dollars spent among the provinces and territories, despite the fact that they only accounted for approximately 16% of the overall Canadian population (CIHI, 2016).

As the Canadian population continues to age, it is imperative that aging research be conducted in order to better understand what can be done to minimize difficulties with aging, and thereby increase the quality of life for those entering old age. In particular, research on healthy aging is becoming an important area of study. A key focus has been towards determining the predictors of healthy aging and how some people have more difficulties aging well (Depp & Jeste, 2006; Depp et al., 2007). Gaining more insight regarding predictors of healthy aging will contribute to future strategies that may help to improve many people's lives in our aging population.

2.2 Healthy Aging

2.2.1 Evolution of Concept of Healthy Aging

As the global population continues to age, there has been a growing interest in research to investigate the factors that allow us to age well (Depp et al., 2007). The concept of healthy aging has been investigated for several decades, with historical accounts of the term 'successful aging' having been reported as far back as the late Renaissance period (Gilleard, 2013; Østbye et al., 2006). However, it was not until the 1950s that the modern gerontological idea of successful aging truly emerged, and later became crystallized in the work by John Rowe and Robert Kahn (Katz & Calasanti, 2015).

Throughout the literature, a number of interchangeable terms have been used to describe healthy aging. These can include, but are not limited to, successful aging, productive aging, positive aging, optimal aging, independent aging, and effective aging (Katz & Calasanti, 2015).

Robert Havighurst was one of the original researchers to use the term 'successful aging' in the first gerontological issue of *The Gerontologist* in 1961, and over the past 50 years, the concept of healthy aging has been further developed by a number of models and theories (Katz & Calasanti, 2015; Tate, Lah, & Cuddy, 2003). *Activity theory* describes aging successfully by way of maintaining our midlife attitudes and activities for as long as possible (Havighurst, 1961). In contrast, *disengagement theory* states that someone who is aging successfully develops an acceptance and desire to disengage from an active life (Havighurst, 1961). *Continuity theory* purports that aging well involves making adaptive choices throughout the aging process and gradually adapting to change and building upon our past experiences (Atchley, 1989). Of these three theories, both activity and continuity theories are most relatable to healthy aging in terms of remaining active physically, cognitively or socially, whereas disengagement theory is not as

relatable and is contradictory to aging well since it posits that individuals refrain from physical, cognitive or social activities as they get older.

The MacArthur studies of successful aging became grounded in Rowe and Kahn's *model of successful aging,* which portrays someone aging well if they avoid disease and disease-related disabilities, maintain high cognitive and physical function, and are actively engaging with life (Bowling & Iliffe, 2006; Rowe & Kahn, 1997). Around the same time as Rowe and Kahn (1997), Baltes and Baltes created an alternative theory to represent someone aging successfully, which they termed the *selective optimization with compensation model* (Baltes, 1997). This theory includes three components: *selection* involves selecting goals while keeping in mind the restrictions of time and energy as we age, *optimization* allocates internal and external resources to achieve these selected goals, and *compensation* uses alternative means to achieve the same goals (Freund & Baltes, 1998).

The *life-course perspective* offers another opportunity to study how well individuals age. This perspective is focused on understanding the biological and behavioural pathways that are associated with physical and social exposures during the gestation period, childhood, adolescence, and adulthood with respect to changes in health and risk of disease in later life (Kuh, Karunananthan, Bergman, & Cooper, 2014). Three models are commonly used to assess these life-course processes: the *critical period model* describes an exposure during a specific period that may have a lifelong effect on organ function or body systems and which cannot be altered in later life, the *pathway model* describes the effect of an earlier exposure (positive or negative) that sets an individual on a path towards a later exposure that may be detrimental or beneficial to their health, and lastly, the *accumulation model* suggests that various factors that increase risk for disease or enhance good health may accumulate gradually across the course of

an individual's life (Heikkinen, 2011). Overall, the life-course perspective is ideal for observing the physical, cognitive, and social changes affecting the health of an individual; health typically peaks in early adulthood and then gradually declines with age (Kuh, 2007). Thus, this perspective offers researchers a unique opportunity to understand the impact of early-life factors and how they may contribute to health outcomes in later life.

Each of these models and theories has its own strengths and weaknesses. The definitions of healthy aging used throughout these models have developed over time to include objective and subjective measures, which will be further discussed in this review (see section 2.2.4). As more research on healthy aging is completed, our knowledge can build from these aforementioned ideas and create better developed theories about what it means to age well.

2.2.2 Definitions of Healthy Aging

There exists a multitude of healthy aging definitions in the literature. The World Health Organization (WHO) considers healthy aging holistically, based on life-course and functional perspectives. They define healthy aging as "the process of developing and maintaining the functional ability that enables well-being in older age" (WHO, 2015 p. 28). Similarly, Health Canada extends the WHO definition by stating that healthy aging is "a lifelong process of optimizing opportunities for improving and preserving health and physical, social and mental wellness, independence, quality of life and enhancing successful life-course transitions" (Health Canada, 2005 p. 5).

The above definitions clearly revolve around one another in the sense that each incorporates some meaning of our ability to function physically, cognitively, and socially, while doing our best to avoid disease and illness, and engage in activities throughout our life. Overall, the main themes found in healthy aging literature are described as either a biomedical approach,

psychosocial approach, or some combination of the two (Bowling & Dieppe, 2005). Since there is no consensual definition of healthy aging, comparing the results across studies can be challenging. In fact, Depp and Jeste (2006) found 29 definitions of healthy aging across 28 different studies. Thus, determining a standard definition of healthy aging is an ongoing process, and one that will certainly be developed further as more healthy aging research is completed.

2.2.3 Determinants of Healthy Aging

Bowling and Dieppe (2005) conducted a systematic literature review on successful aging and found that the majority of research on this topic falls into three frameworks: biomedical, psychosocial, and lay perspectives. Described previously, the *model of successful aging* introduced by Rowe and Kahn (1997) is one of the most widely used biomedical approaches; however, it fails to address the understanding that living into old age completely disease-free is unrealistic for most people (Bowling & Dieppe, 2005). Psychosocial perspectives bring both psychological and sociological views together. The psychological interpretations of healthy aging are mainly focused on our attitudes, and how we define aging. The sociological interpretations of healthy aging further extend the definition by including social interaction and support structures (Hansen-Kyle, 2005). Lastly, lay perspectives represent an individual's own definition of healthy aging. As such, lay perspectives may include aspects from both biomedical and psychosocial approaches. Lay perspectives offer an opportunity to assess an individual's subjective understanding of healthy aging, which may also reflect some of the objective measures used in biomedical approaches (e.g., presence of disease). This provides a more holistic conceptualization of healthy aging by incorporating elements from both the objective and subjective components of healthy aging (Cosco, Prina, Perales, Stephan, & Brayne, 2014). Overall, this perspective reflects what individuals consider valuable in terms of healthy aging,

with a greater emphasis placed on subjective assessment. Thus, the multidimensionality of the lay-based model and its reflection of the perspective of the individual are important and should be used to evaluate any intervention designed to promote healthy aging (Bowling & Iliffe, 2006).

2.2.4 Components of Healthy Aging

There are a number of components that have been used to develop the healthy aging definitions found throughout the literature. Research completed by Depp and Jeste (2006) found that the most common component was disability and physical function, which was generally measured using self-reported ADLs and IADLs. Additionally, cognitive function was a frequent component in the definitions of healthy aging, and was often assessed with the use of cognitive screening tests such as the MMSE, or by self-reported memory function (Depp & Jeste, 2006). Lastly, social function, as well as life satisfaction and well-being, are other components often found among the healthy aging definitions.

In a more recent review of the literature, researchers Cosco et al. (2014) attempted to provide a snapshot of the operationalizations used to define healthy aging and found 105 operational definitions across 84 studies. Of these definitions, 92.4% of them included physiological constructs (e.g., physical or cognitive function), 49.5% included constructs requiring engagement (e.g., active life or social engagement), 48.6% included constructs of well-being (e.g., life satisfaction), 25.7% included individual resources (e.g., resilience), and lastly, 5.7% included extrinsic factors (e.g., finances). An example that encompasses many of these constructs of healthy aging may include asking participants how strongly they agree with the phrase “I am aging successfully” (Strawbridge, Wallhagen, & Cohen, 2002), as this phrase can have a different meaning for each individual based on what they consider the most important for aging well (e.g., physical or cognitive function, or social engagement).

Based on this snapshot of healthy aging definitions, key constructs often include measuring some form of physical and cognitive function, but an additional measure, social engagement, should also be considered just as important for inclusion in these definitions. For example, Rowe and Kahn's model of successful aging (1997) includes an active engagement with life component, along with the physical and cognitive components of aging well. Additional social engagement measures in other healthy aging definitions have included measuring satisfaction among social relationships (White, St. John, Cheverie, Iraniparast, & Tyas, 2015), and measuring how often individuals have monthly contact with more than three friends or relatives (Strawbridge et al., 2002).

2.2.4.1 Cognitive Health

Cognitive heath is a crucial component of healthy aging. It may be argued that our cognitive resources are the most important part of maintaining our everyday function (Poon et al., 1992). Moreover, cognitive function may be considered as a key determinant of our quality of life and of maintaining independence into old age (Seeman, Albert, Lusignolo, & Berkman, 2001). Indeed, research has demonstrated that level of education, acquired knowledge, and engagement in the community all help individuals remain alert, cognitively intact, and healthy (Hansen-Kyle, 2005). Moreover, independence can be maintained when cognitive function is intact, but when cognitive impairment occurs, independence becomes less sustainable (Poon et al., 1992). As such, cognitive function is especially important for healthy aging, because without including this component, healthy aging cannot be assessed properly (Hansen-Kyle, 2005).

Overall, cognitive function is a truly complex domain that encompasses intelligence, executive function, memory and learning, and information processing (Rizzo & Eslinger, 2004).

Operationalization of the cognitive function component of healthy aging often includes using the MMSE with various cut-off points such as scores of 24 or greater (Almeida, Norman, Hankey, Jamrozik, & Flicker, 2006), 26 or greater (Tyas et al., 2007), or scores greater than or equal to 78 on the Modified Mini-Mental State Examination (3MS) (Hogan, Fung, & Ebly, 1999; White et al., 2015). In addition to these measures of global cognitive function, specific cognitive domains, such as memory (e.g., short-term recall), have also been considered in the definitions (Andrews, Clark, & Luszcz, 2002; Tyas et al., 2007).

Cognitive function is important for our health, longevity, and quality of life because as we age there is the possibility of a great deal of variability with regard to our cognitive abilities (Rizzo & Eslinger, 2004). Thus, based on previous healthy aging research and the role that cognitive function plays, it is imperative that this component be incorporated into any construct of healthy aging used in future aging research.

2.2.4.2 Physical Health

Physical heath is another fundamental component of healthy aging. The benefits of physical exercise as it relates to health have been widely documented. Engaging in regular exercise typically helps individuals reduce or avoid disability (Lachman & Agrigoroaei, 2010). In general, physical activity peaks in young adulthood and declines progressively with each decade, varying among individuals (McMurdo, 2000). Moreover, the best evidence to support healthy aging includes two lifestyle factors: physical exercise and caloric restriction, with the latter associated more often with longevity (Depp et al., 2007).

The measures most commonly used to assess physical function and disability are ADLs and IADLs (Depp & Jeste, 2006), both of which have been found to be accurate measures of health and aging (Hansen-Kyle, 2005). The index of ADLs was created in order to study

treatment and prognosis among older adults and chronically ill individuals (Katz, Ford, Moskowitz, Jackson, & Jaffe, 1963), and is one of the most widely used and accepted measures of function in gerontological literature (Satariano, 2006). The ADL index is used to assess the extent to which someone requires assistance with basic tasks (e.g., bathing, dressing, toileting, and feeding) that are necessary for living independently. While ADLs were designed to assess independence, IADLs were created to assess adaption to the environment—in other words, a higher level of function (e.g., telephone use, taking medications, handling money, and shopping) (Satariano, 2006).

The disability and physical function component of heathy aging has been operationalized as having no ADL disability (Jorm et al, 1998), not having to use a wheelchair or not needing help while walking outside (Roos & Havens, 1991), having no ADL disability and less than one IADL disability (Menec, 2003), and being independent on seven ADLs and seven IADLs (White et al., 2015). The healthy aging measure developed by Tyas et al. (2007) also incorporated ADLs and IADLs using a range of 0 to 5 for both, with various cut-off points for each level of healthy aging (i.e., excellent, very good, good, and not healthy aging). Other measures have also included tracking the number of steps to turn 360 degrees as fast as possible without falling (Baltes & Lang, 1997), and time spent gardening, engaging in exercise, and taking walks (Garfein & Herzog, 1995).

Clearly, physical function has been included in many definitions of healthy aging (Sargent-Cox, Butterworth, & Anstey, 2015). Physical function and cognitive function are interrelated, such that cognitive changes (e.g., cognitive decline) may affect abilities of physical function, and therefore both should be included in definitions of healthy aging (Satariano, 2006).

2.2.4.3 Self-Assessment of Health

Self-assessment offers a valuable source of data on participant health status; specifically, it allows researchers to understand global health status in a way that nothing else can (Idler & Benyamini, 1997). In fact, research has found over the years that self-rated perceptions of older adults' health and well-being may be considered at least as important as other objective data predicting their health over the course of their life (Blazer, 2008).

The addition of a self-rated health component has become regular practice throughout psychosocial, gerontological, and epidemiological studies. This component is considered to be an accurate indicator of overall health, and provides a valid, reliable, and cost-effective way to assess healthy aging (Kaplan & Baron-Epel, 2003). In a study completed by Strawbridge et al. (2002), a comparison was made between self-rated definitions of successful aging and Rowe and Kahn's model of successful aging. According to the results, 50.3% of participants classified themselves as aging successfully, but when compared against Rowe and Kahn's model, only 18.8% satisfied the criteria. This result indicates that a larger proportion of individuals consider themselves to be aging well than would be indicated by the most well-known definition of successful aging defined by Rowe and Kahn (Strawbridge et al., 2002).

Self-rated health is often measured using a single-item question asking participants to rate their overall health using a scale (e.g., excellent, very good, good, fair, and poor) (Krause & Jay, 1994). In other words, self-rated health can be considered as a summary statement of an individual's overall health within their own perceptual framework (Kaplan & Baron-Epel, 2003). Other measurements of self-rated health have included a more condensed scale of overall health from 'excellent' to 'fair' (Roos & Havens, 1991), or a larger scale asking participants to rate how well they are aging from 1 (least successful) to 10 (most successful) (Montross et al., 2006).

Self-rated function offers another way of assessing the health of an individual. In a study completed by Greiner, Snowdon, and Greiner (1996), the relationship between self-rated health and self-rated function was explored using data from the Nun Study. Self-rated function consisted of asking participants to rate their ability to take care of themselves compared to others, using a five-level scale ranging from excellent to poor. Overall, in the Nun Study, self-rated function had a stronger association with ADLs and mortality than self-rated health.

Healthy aging is a multifaceted concept (Strawbridge et al., 2002), and self-rated health and function are both complex components unique to each individual (Kaplan & Baron-Epel, 2003). Self-assessment of health provides an opportunity to assess global health and the potential changes in health an individual may be experiencing throughout their life. Thus, self-rated health or function should be incorporated into healthy aging definitions in order to better assess an individual's health status (Idler & Benyamini, 1997).

2.2.5 Predictors of Healthy Aging

One of the primary goals of healthy aging research is to determine the genetic and environmental determinants of aging in good health in order to fully understand the interactions that are involved between the two. Demographic characteristics, health behaviours, and genes are the predictors of healthy aging that have been studied the most (Depp et., 2007), and these predictors may also often appear as components in the definitions of healthy aging.

In a review of the literature, researchers Peel, McClure, and Bartlett (2005) summarized existing evidence surrounding behavioural determinants of healthy aging. They found predictors of healthy aging such as smoking status (i.e., being a nonsmoker), alcohol consumption (i.e., drinking moderate amounts of alcohol), and lastly, physical activity (i.e., having high levels of physical activity) predicted subsequent healthy aging. Similar predictors of healthy aging were

reported in the systematic review by Depp and Jeste (2006). Age (i.e., being younger) was considered a highly indicative predictor of healthy aging, along with the absence of hearing problems or arthritis, the ability to complete a greater number of ADLs, and being a nonsmoker. Other predictors of healthy aging included having low systolic blood pressure, taking fewer medications, absence of depression, better self-rated health, higher income and educational level, and being White.

More recent studies have continued to report the aforementioned predictors of healthy aging. Older adults who attained a higher level of education generally report better health, higher life satisfaction, and a greater interest in life by engaging in social activities (Sowa, Tobiasz-Adamczyk, Topór-Mądry, Poscia, & Ignazio la Milia, 2016). Individuals who adopt a healthy lifestyle not only live a longer life, but tend to live longer in better health. This may be made achievable by refraining from smoking, unhealthy dietary behaviours, physical inactivity, and heavy drinking. Indeed, in a review focused solely on lifestyle predictors of healthy aging in men, engaging in physical activity and refraining from smoking were two of the key predictors of healthy aging (Södergren, 2013). Adoption of a healthier lifestyle may also include having a social network. Engaging in social activities with friends or family as well as participating in voluntary work or religious practices have been found to be positively related to improvements in physical health and psychological well-being, and reductions in functional decline and depression (Sowa et al., 2016). Thus, the adoption of a healthier lifestyle may result in the postponement of disease and disease-related disabilities with age, which may consequently allow for a longer period of independent living and reduce the health-related stress for individuals and for society (Södergren, 2013).

Lastly, there have been hundreds of studies that have examined the association between genes and longevity, but few have examined this association as it relates to healthy aging (Depp et al., 2007). One particular gene that has garnered a great deal of interest is apolipoprotein E (*APOE*), specifically the ε4 allele. Individuals who carry this particular allele are at an increased risk of developing Alzheimer's disease, a disease that significantly impacts the health of an individual in terms of their physical and cognitive abilities, as well as their level of independence (Reinvang, Espeseth, & Westlye, 2013). Indeed, research has found that among non-demented older adults with the *APOE*-ε4 allele, performance on cognitive tasks was reduced, and there was atrophy in the hippocampus and amygdala (Honea, Vidoni, Harsha, & Burns, 2009). Clearly, the presence of this gene, in particular the ε4 allele, can have detrimental effects on the capabilities of aging well, and should continue to be researched.

The aforementioned predictors of healthy aging offer a small sample of what research has been able to discover thus far. These predictors have been found to significantly improve the likelihood of aging well, suggesting that being physically active, being a nonsmoker, and actively engaging in cognitive and social activities can enhance healthy aging.

2.3 Emotions

Emotions are central to the human experience. The embodiment of emotions is uniquely manifested in behavioural patterns of facial expression and autonomic arousal (Dolan, 2002). Conceptually, emotions often fit into discrete categories of emotion families such as joy, happiness, anger, and fear (Fredrickson, 2001). Additionally, emotions are often brief, whereas an additional component of emotions, known as affect, is more long-lasting and is involved in other affective phenomena such as physical sensations, moods, and attitudes (Fredrickson, 2001).

Emotional processing involves the interplay between both cognitive and physical functions. A complex network of cortical structures, such as the limbic system and reticular formation found in the brainstem, functions as the emotional processing system of the brain (Noback, Strominger, Demarest, & Ruggiero, 2005). In addition, the autonomic nervous system helps regulate bodily functions, such as heart rate and respiration, and may also be viewed as a major component of the emotional response (Kreibig, 2010). The interactions between the limbic system, reticular formation, and autonomic nervous system have implications in cognitive and physical functions that may contribute to how well someone is aging.

2.3.1 Cognitive Effects of Emotions

2.3.1.1 The Limbic System and Reticular Formation

One of the structures that is involved in controlling emotional behaviours lies in the forebrain and is known as the limbic system (Porter & Knight, 2009). The limbic system is involved in various functions such as the *conscious feeling of emotions,* which is largely processed within the cingulate and prefrontal cortices; *emotional reactions* towards dangerous or aversive stimuli; *emotional reactions* towards positive or pleasurable situations; and lastly, *emotional actions,* which become activated and guide goal-directed behaviour (Noback et al., 2005). Various brain structures, such as the amygdala, which processes emotions, and the hippocampus, which consolidates information from short-term to long-term memory, make up the limbic system. Neurodegeneration primarily affects the limbic structures dedicated to memory, such as the hippocampus, which may lead to memory deficits (Catani, Dell'Acqua, & de Schotten, 2013). Furthermore, individuals with the *APOE*-ε4 allele are at an increased risk for developing Alzheimer's disease, a type of dementia that causes memory and behavioural problems, thus affecting how well individuals age (Honea, Vidoni, Harsha, & Burns, 2009).

Indeed, research by Tyas et al. (2007) found that the presence of both stroke (i.e., brain infarcts) and Alzheimer neuropathology dramatically decreased the possibility for an individual to age well.

Much like the limbic system, the reticular formation reflects an important component in regards to the cognitive effect of emotions. The reticular formation is a highly organized set of neurons located in the tegmental part of the brainstem that receives sensory information from the peripheral nerves and significantly influences the level of arousal (Noback et al., 2005). Collectively, the reticular formation and limbic system function together and are linked to emotional and behavioural expressions (Noback et al., 2005).

2.3.1.2 The Broaden-and-Build Theory

The broaden-and-build theory is a key conceptual framework developed by Fredrickson (1998) that describes the psychological benefit of positive affect. Specifically, certain discrete emotions such as joy, interest, love, and contentment are all able to broaden an individual's momentary thought-action repertoires and build long-lasting physical, intellectual, social, and psychological resources (Fredrickson, 2001). In other words, broadening may be referred to as widening an individual's attentional scope through positive affect, which encourages developing connections and promoting additional global information processing (Fredrickson, 2004; Cameron, Bertenshaw, & Sheeran, 2015). By broadening, positive emotions may then lead to the discovery of new and imaginative actions, ideas, and social relationships, which subsequently builds an individual's personal resources (Fredrickson, 2004). These resources range from physical and intellectual to social and psychological resources, all of which can function as reserves that can be drawn upon in order to increase the chance of living a longer life

(Fredrickson, 2004). As such, positive emotions may protect against cognitive decline and may contribute to healthier aging outcomes.

2.3.2 Physical Effects of Emotions

The autonomic nervous system is composed of three major subdivisions: the sympathetic, the parasympathetic, and the enteric nervous system. The sympathetic nervous system controls the fight or flight response during emergency situations; under normal circumstances, the parasympathetic nervous system is responsible for autonomic functions, such as heart rate and respiration; and lastly, the enteric nervous system regulates food processing and modulates secretory gland activity (Robertson, Low, & Polinsky, 2011).

An increasing number of studies have focused on the relationship between physical health and positive affect. For example, positive affect may influence health through biological routes, such as modifying the immune system, but also through behaviours that people engage in to promote health, such as physical activity (Cameron et al., 2015; Pressman & Cohen, 2005). The interactions between emotions and the autonomic nervous system strongly suggest the possibility that lifelong emotional arousal can affect health and longevity (Danner et al., 2001).

Researchers Ong, Mroczek, and Riffin (2011) have outlined four pathways by which positive emotions may contribute to health outcomes in adulthood and later life: health behaviours, physiological systems, stress exposure, and stress reactivity and recovery. Prospectively, positive emotions have been associated with more *health-enhancing behaviours* and restorative sleep quality. Increasing evidence has suggested that positive emotions may alter risk for disease in the neuroendocrine, immune and cardiovascular systems by dampening the adverse effects on the body associated with prolonged activation of these *physiological systems*. In particular, decreases in positive emotions may be accompanied with over-activation of the

hypothalamic-pituitary-adrenal (HPA) axis, which is a central component of the stress response and neuroendocrine system, thus leading to downstream damage via the by-products of the HPA axis, such as excess cortisol and inflammatory cytokines (Mroczek et al., 2013). Positive emotions may also have a direct effect on health outcomes by lowering the overall *stress exposure*. For example, prospective studies involving community-dwelling older adults have found an association between positive emotions and reduced exposure to acute health conditions, such as stroke and myocardial infarction (Ong et al., 2011; Pressman & Cohen, 2005). Lastly, in terms of *stress reactivity and recovery*, positive emotions may act as a buffer to ameliorate the adverse effects of stress. In summary, these four suggested pathways signify that relationships are likely to exist between emotions and health outcomes in later life.

2.3.3 Emotions and Longevity

Using Nun Study data, Danner et al. (2001) focused their research on the association between early-life emotions and longevity. A very strong association was found between positive emotional content written in autobiographies in early adulthood and longevity nearly six decades later. Idea density and grammatical complexity were taken into consideration based on previous Nun Study findings, which reported that linguistic ability in early adulthood was associated with survival in late adulthood (Snowdon et al., 1999). Indeed, these previous results found idea density to have the strongest influence on longevity, with a one-unit decrease (i.e., one fewer idea per ten words) in idea density being associated with a 49% increase in the mortality rate.

Additional studies have determined associations between positive emotions and longevity. Pressman and Cohen (2012) focused their research on the assessment of positive emotion word use and longevity. Autobiographies from deceased psychologists were coded using a 34-item scale in which positive and negative words were categorized as activated (e.g.,

active, energetic, and vigorous), or not activated (e.g., peaceful, relaxed, and cheerful). Much like the results reported by Danner et al. (2001), an association was discovered between activated positive emotion words and increased longevity, even after accounting for additional covariates, such as sex and age.

A recent meta-analysis was conducted in 2016 by researchers Zhang and Han, who were interested in examining the potential association between positive affect and mortality among a group of healthy community-dwelling older adults. Examples of search terms used to define positive affect included 'positive emotions', 'happiness', and 'optimism.' These researchers found that having higher positive affect was associated with lower mortality risk even after taking into consideration medical, psychological, and social factors. Thus, this study provides another example associating positive emotions and longevity.

A somewhat different approach was undertaken by researchers Mroczek et al. (2013), in which emotional reactivity was assessed with respect to longevity. Emotional reactivity was defined as any changes in positive or negative affect reported throughout the day in response to daily stressors. The sample for this study included all males ages 58 to 88 from the Veteran Affairs Normative Aging Study. Each participant was asked to complete an 8-day daily diary, which included various surveys focused on emotional reactivity (e.g., the Daily Inventory of Stressful Events and the Positive and Negative Affect Schedule (PANAS)). Overall, positive emotional reactivity was associated with longevity, such that decreases in positive affect assessed by the diaries were found to double the risk of mortality almost a decade later, whereas negative emotional reactivity was not found to be a predictor of mortality.

Lastly, studies have also focused on the possible associations between subjective well-being and longevity. The first study used data from 10 follow-up assessments over the course of

22 years and included participants ages 62-101 years at baseline (Gana, Broc, Saada, Amieva, & Quintard, 2016). Subjective well-being components included life satisfaction, positive affect, and negative affect. Among the subjective well-being components, only positive affect was associated with longevity even in the presence of other covariates (e.g., age, gender, and education), and after adjusting for the interaction between positive and negative affect. The second study used data over a 28-year period from the Alameda County Study (Xu & Roberts, 2010). The subjective well-being components from this study included positive feelings, domain life satisfaction, positive affect, and negative feelings. Overall, subjective well-being and the various positive components were found to be associated with longevity, whereas negative feelings were not.

In summary, the aforementioned studies on emotions and longevity found significant associations between positive emotions and longevity, even after controlling for additional covariates. Although no significant associations were found between negative emotions and longevity, negative emotions should continue to be explored as there are few studies reporting its impact. Living a longer life may be indicative that an individual is in good health, but longevity does not necessarily equate to healthy aging (Depp et al., 2007). Thus, exploring the association between emotional expressivity and healthy aging is necessary in order to clarify this distinction and discover the potential of emotions as predictors of healthy aging that may be modifiable and beneficial for living a healthier life.

2.4 Emotions and Healthy Aging

The literature surrounding a potential association between emotions and healthy aging is sparse. Specific healthy aging constructs that incorporate the physical, cognitive, and self-assessment components mentioned previously have not been used in the following studies, but

instead health behaviours and health-related psychosocial factors have been used. In a recent study by Sin et al. (2015), they attempted to find an association between positive affect (measured using a subscale of the PANAS) and health behaviours (i.e., physical activity, sleep quality, medication adherence, alcohol use, and smoking status). Their sample was derived from the Heart and Soul Study, including patients (mainly older adult males) with coronary heart disease who completed a series of surveys once at baseline, and again five years later. A significant association was found, using baseline data, between positive affect and the previously mentioned health behaviours, except for alcohol use. Positive affect did not predict health behaviours at the follow-up five years later once the baseline health behaviour data had been incorporated, but the results did find that increases in positive affect after the five-year follow-up did co-occur with improvements in physical activity, sleep quality and medication adherence.

A separate study focused on the association between positive and negative affect and health-related psychosocial factors using participants from the Whitehall II cohort, ages 58 to 72 (Steptoe et al., 2008). The ecological momentary assessment survey was used to assess positive and negative affect over the course of one day. Health-related factors were assessed using several questionnaires that contained measures such as socio-economic and demographic information, social support, and sleep quality. Overall, a significant association was found between positive affect and health-related psychosocial factors such as social connectedness, social support, and optimism. Negative affect was also found to be associated with chronic stress and negative social support.

Despite the significant results reported from these studies, both were cross-sectional in design, and therefore, the direction of causality cannot be inferred. Furthermore, a specific

healthy aging construct was not used in either of these studies, but instead this measure was assessed more broadly in terms of behaviours and psychosocial factors.

Although not specifically related to healthy aging, an additional study focused their research on the association of emotional expressivity with dementia and Alzheimer's disease (Morrison, 2015). Dementia refers to a progressive decline in cognitive abilities that leads to functional deficits; Alzheimer's disease is the most common subtype of dementia, and both dementia and Alzheimer's disease clearly reflect the opposite of what it means to age well. Using data from the Nun Study, Morrison found that the association of emotional expressivity with dementia was modified by idea density, and that there was an interaction between positive and negative emotional expressivity. Among individuals with high idea density and low positive emotional expressivity, negative emotions significantly increased risk of dementia even after adjusting for age and *APOE*-ε4 status. The results reported in this study suggest that if associations exist between emotional expressivity and dementia, then an association between emotional expressivity and healthy aging may also exist, and it may be modified by idea density.

2.5 Summary

The literature surrounding emotions and healthy aging is limited. While studies have assessed associations with longevity, this term alone does not necessarily reflect what it means to age well.

Healthy aging in and of itself has been a difficult concept to define. Multiple models and theories have been created, such as the model of successful aging by Rowe and Kahn (1997) or the selective optimization with compensation model by Baltes and Baltes (1997). Various components of healthy aging such as physical function (e.g., ADLs and IADLs), cognitive function (e.g., MMSE), and self-assessment of health (e.g., self-rated health questionnaires) have

been used to define healthy aging in these models. Every theory and model has its own strengths and weaknesses, and more research is needed to help clarify the concept of healthy aging, as a standard definition does not exist.

A number of studies have focused on the association between emotions and longevity. Emotions are central to the human experience, and can include both cognitive and physical components. The cognitive effects of emotions are driven by the limbic system, which is involved in controlling emotional behaviours, whereas the physical effects of emotions are driven by the autonomic nervous system, which plays an important role with regards to health and longevity.

As the population continues to age, it is important to find novel ideas and methods to maintain or improve our health in order to age more successfully. Investigation of the association between emotional expressivity in early adulthood and healthy aging in late adulthood will provide the opportunity needed to enhance our knowledge in this area, and may lead to improvements in our quality of life in late adulthood.

Chapter 3

Study Rationale and Research Questions

3.1 Study Rationale

The current research project builds upon the findings from the previously mentioned study by Danner et al. (2001) in which emotional expressivity in early adulthood was strongly associated with longevity six decades later, using data from the Nun Study. Specifically, those who expressed more positive emotions were more likely to live a longer life than those who expressed fewer positive emotions. Furthermore, a study completed by Morrison (2015) demonstrated that significant associations exist between emotional expressivity and dementia in the Nun Study, which may suggest that associations are possible between emotional expressivity and healthy aging. The consistent associations found between positive emotions and longevity, as well as the associations found between emotional expressivity and dementia, all provide the rationale for a possible association between emotions and other health outcomes in later life, such as healthy aging.

One possible explanation for the associations found throughout the various studies could be that positive emotions have a protective effect against cognitive or physical decline, thereby providing better health outcomes in later life. Given the literature on healthy aging, as well as the plethora of emotions literature, an attempt should be undertaken to determine if an association exists between emotional expressivity and healthy aging. Thus, the current research project aimed to build on the knowledge regarding emotions as well as healthy aging in order to discover whether an association exists.

The associations found between emotional expressivity in early adulthood and healthy aging in late adulthood may be used to support future public health interventions that promote

healthy aging. Interventions could be created which include physical, cognitive, and social activities that are structured to maximize the expression of more positive emotions and fewer negative emotions. As more individuals incorporate positive emotions in their daily lives, this may lead to a greater number of people in the population aging well, positively impacting quality of life and reducing the need for health-rated care in older age.

3.2 Research Questions and Hypotheses

1) Is overall emotional expressivity (positive and negative) in early adulthood associated with healthy aging?

    Hypothesis: Overall emotional expressivity is positively and significantly associated with aging well.

2) Is positive emotional expressivity in early adulthood associated with a higher likelihood of healthy aging?

    Hypothesis: High positive emotional expressivity, reflected in having a higher number of positive emotion words in the participants' autobiographies, is positively and significantly associated with a higher likelihood of aging well.

3) Is negative emotional expressivity in early adulthood associated with a lower likelihood of healthy aging?

    Hypothesis: High negative emotional expressivity, reflected in having a higher number of negative emotion words in the participants' autobiographies, is negatively and significantly associated with a lower likelihood of aging well.

Chapter 4

Methods

4.1 Literature Search

A systematic search was conducted in June 2018 in order to identify all relevant literature regarding emotional expressivity in early adulthood and healthy aging in late adulthood. Two separate systematic searches were completed using the PubMed and PsycINFO databases. The PubMed database included all articles that were published from 1950 onwards. For the full literature search template, please refer to Appendix A. The literature search was restricted to human participants. Search terms for "emotional expressivity" and "healthy aging" and "late life" were considered. The PubMed literature search retrieved 302 articles before additional screening.

A second search was conducted using the PsycINFO database (1840 to present) in June 2018. This search was also restricted to human participants. For the full literature search template, please refer to Appendix A. PsycINFO index terms related to "emotional expressivity" and "healthy aging" and "late life" were used. The PsycINFO literature search retrieved 237 articles before additional screening.

All articles that were retrieved from each database were excluded if the exposure was not related to emotional expressivity and the outcome was not related to healthy aging. After applying the exclusion criteria, a total of 8 articles from PubMed and 6 articles from PsycINFO were retrieved. After removing duplicate articles, a final total of 10 remained and are summarized in Appendix B.

4.2 Data Source: The Nun Study

4.2.1 Background

The Nun Study is a longitudinal study of aging and health (Snowdon et al., 1996). The study originally began in 1986 when Dr. David Snowdon conducted a pilot study that focused on a small group of religious sisters from the School Sisters of Notre Dame in Mankato, Minnesota, USA. This initial pilot study was later expanded to include members from the Midwestern, Eastern, and Southern United States (Snowdon et al., 1997).

The Nun Study provides a unique opportunity to examine factors across the lifespan. Participants from the Nun Study had comparable lifestyles and living environments throughout the course of their adult lives, providing a high level of homogeneity that reduces or eliminates many potential confounders (Tyas et al., 2007). Conditions such as reproductive and marital histories, social activities and support, smoking, and drinking alcoholic beverages were similar across participants. Additionally, the sisters had comparable income, housing, and access to food and health services. The majority of the sisters worked as teachers, while a smaller number worked as house sisters responsible for household work in the convent.

4.2.2 Population

Between years 1991 through 1993, members of the School Sisters of Notre Dame who were living in the United States and who were born before 1917 (aged 75 years or older) were invited to participate in the Nun Study (Snowdon et al., 1996). From a potential 1,031 eligible sisters, a total of 678 (66%) agreed to take part throughout the entire study process, which included a review of archival and medical records, cognitive and physical assessments performed annually, and brain donation following death (Snowdon at el., 1997). When testing first began in 1991, the participants were between the ages of 75 to 102, with an average age of 83 (Danner et

al., 2001). Nonparticipants did not differ significantly from participants in terms of their age, race, place of birth, and mortality rates (Snowdon et al., 1996).

4.2.3 Autobiographies

During September of 1930 the Mother Superior of the North American sisters sent out a letter requesting that all sisters write an autobiography that outlined their own life, using no more than two to three hundred words, written on a single sheet of paper (Danner et al, 2001; Snowdon et al., 1996). These autobiographies have become very useful for better understanding the information contained within each narrative, such as the sisters' place of birth and parentage, interesting events from their childhood, influences that led to joining the convent, as well as any other outstanding events (Patzwald & Wildt, 2004). The instructions for writing the autobiographies were not intended to influence the way in which the sisters described their life events, nor were they intended for studying emotional content. Instead, it is suspected that the autobiographies may have been used to collect information to help determine educational and occupational paths in the future (Danner et al., 2001). Each autobiography reflected the sister's individual style of writing, which ranged from simply stating their life events to more elaborate emotional accounts (Danner et al., 2001). Autobiographies were selected for further analysis as long as they were handwritten by sisters who were born and raised in the United States and were proficient in English (Danner et al., 2001). The autobiographies meeting these criteria were acquired from participants of the Milwaukee, Wisconsin and Baltimore, Maryland convents who took their religious vows between 1931 and 1943 (Snowdon et al., 1999). In total, 180 autobiographies were coded for emotional expressivity (i.e., words classified as positive, negative, or neutral), idea density, and grammatical complexity (Danner et al., 2001).

4.3 Analytic Sample

To assess the association between emotional expressivity in early adulthood and healthy aging in late adulthood, the analytic sample was restricted to participants with scored hand-written autobiographies (n=180) (see Figure 1). Additionally, participants were also excluded if they were missing data on age at first cognitive assessment, age at the time the autobiography was written, educational attainment, *APOE*-ε4, idea density, or grammatical complexity. Participants missing data on measures used to create the healthy aging outcome variable (i.e., MMSE, delayed word recall, ADLs, IADLs, and self-rated function), were also excluded.

Of the original 180 coded autobiographies, 164 (91.1%) were initially considered as the analytic sample to be used for statistical analyses. However, when adjusting for level of educational attainment, models were not viable, given the few participants with a high school degree or less (n=15). Thus, to better control for possible confounding, the sample was restricted by education, which then allowed all models to run without issues. Therefore, a final analytic sample of participants restricted by their level of education (i.e., those with a Bachelor's degree or higher) was used for the remaining analyses. The education variable was then dichotomized as Master's degree or higher vs. Bachelor's degree. After restriction, the new analytic sample had 149 individuals (i.e., 82.8% of the original 180 participants). Tables were created to assess possible selection bias in the analytic sample and may be found in Appendix E.

4.4 Measures

Figure 2 illustrates a timeline of relevant Nun Study variables.

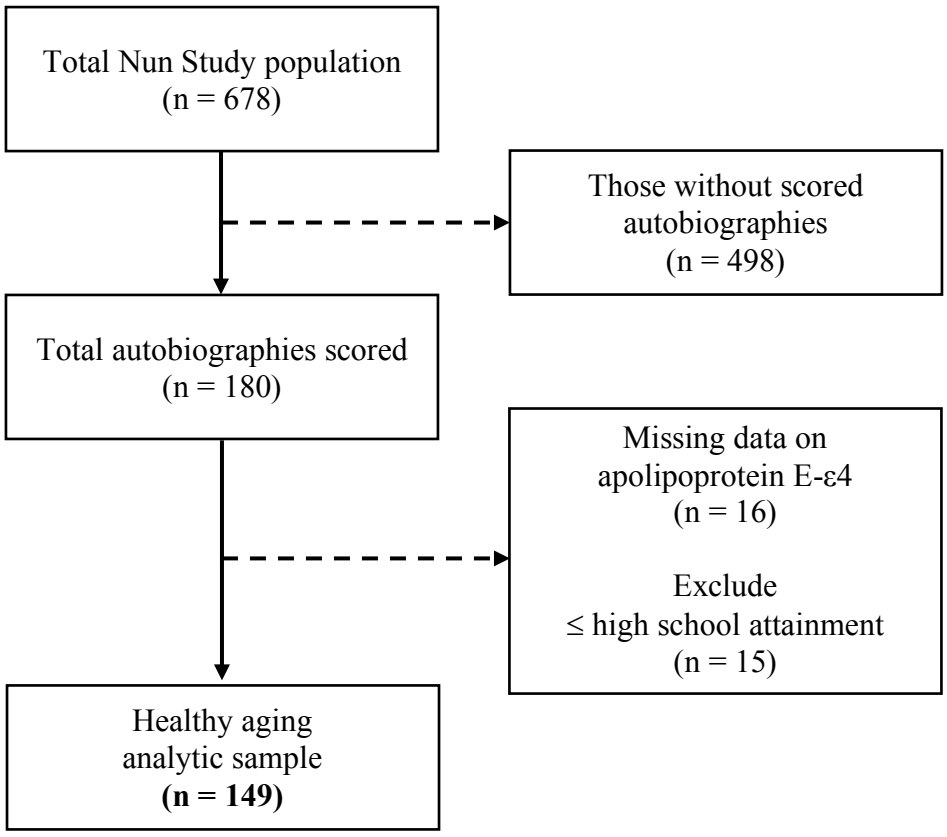
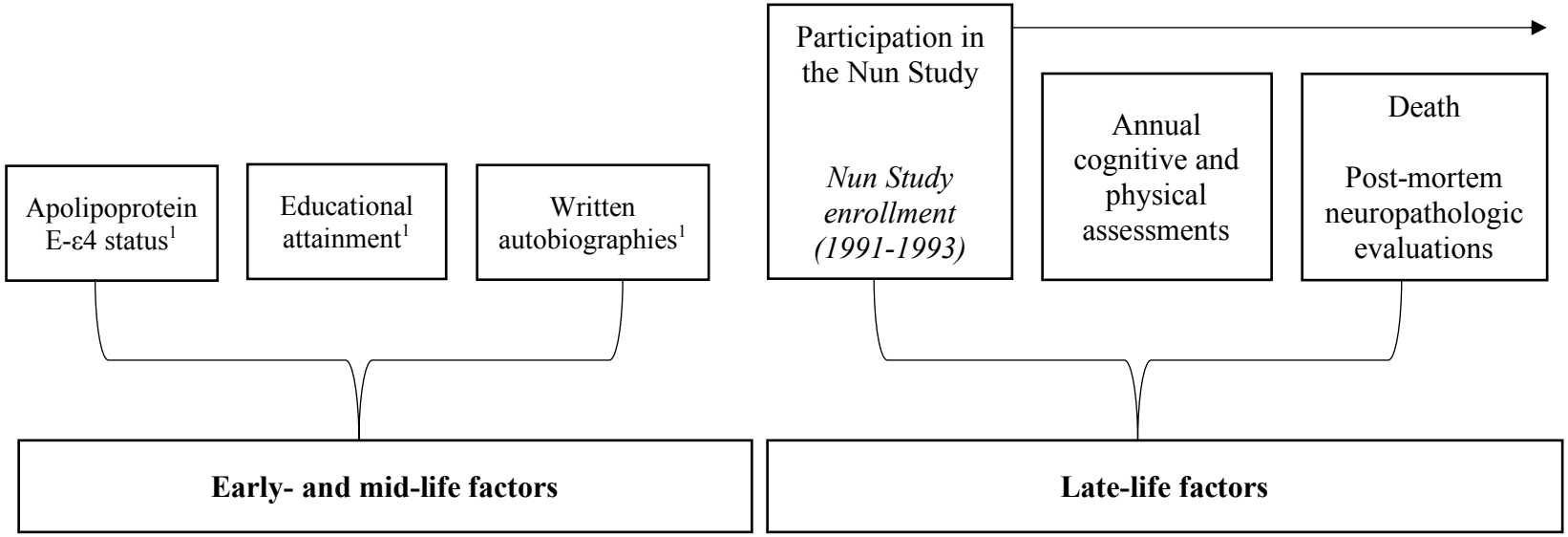


Figure 1. Flowchart of Analytic Sample

***** No missing data for education, idea density, grammatical complexity, age at first cognitive assessment, age at the time the autobiography was written, or measures used to create the healthy aging outcome



[1]Educational attainment, written autobiographies, and *APOE*-ε4 status are exposures that occurred prior to the start of the Nun Study. Data on *APOE*-ε4 status were collected during the course of the Nun Study along with coding of data from the written autobiographies (e.g., emotional expressivity, idea density, and grammatical complexity).

Figure 2. Timeline of relevant Nun Study variables

4.4.1 Exposure Measures

Measures of emotional expressivity were assessed from the handwritten autobiographies, described previously. Two coders reviewed the 180 autobiographies, counted all words that reflected an emotional experience, and classified this emotional content by valence as positive, negative, or neutral. A third coder then verified the coding of each word for accuracy. This coding system was created to have face validity with other similar studies using emotional coding techniques (Danner et al., 2001). A detailed description of the complete methods used to code emotional expressivity in the autobiographies is described elsewhere (Danner et al., 2001).

Measures of overall (i.e., the sum of positive and negative emotions), positive, and negative emotional expressivity were included in all statistical analyses and categorized based on within-convent ranking of the respective raw word counts to control for differences in the distribution of emotional expressivity across convents. Each measure was first assessed as quartiles, and later collapsed into two categories in order to achieve viable results using both the two and four-level healthy aging outcomes. Overall and positive emotional expressivity were dichotomized as "high" (top quartile) vs. "low" (bottom three quartiles), while negative emotional expressivity was dichotomized as "high" (top three quartiles) vs. "low" (bottom quartile). These different dichotomies were necessary, as they allowed all statistical analyses to work without issue (i.e., no quasi-complete separation of data points) using the two and four-level healthy aging outcomes, thus maintaining consistency for each exposure. Quasi-complete separation of data points may occur when the sample size is too small or when attempting to include a larger number of variables in the models, indicating that some of the data may be too sparse for the statistical analyses to run properly. Thus, to address this issue, variables were collapsed into at least two categories to improve the viability of the models. Negative emotional

expressivity did not yield equally distributed groups when assessed as quartiles (i.e., quartiles two and three were the largest), possibly caused by the limited expression of negative emotions in the autobiographies; in other words, the number of negative emotion words was not continuous and could not be categorized equally. Thus, negative emotional expressivity was dichotomized differently from overall and positive emotional expressivity to best capture the higher and lower use of negative emotions from the autobiographies.

4.4.2 Outcome Measures

A healthy aging construct using performance-based measures of cognitive and physical function (i.e., MMSE, delayed word recall, ADLs, IADLs), as well as self-rated function (Tyas et al., 2007) was used. The data used to construct healthy aging were acquired from the first assessment in later life (baseline age 75 years or older) as more data on the participants were available at this assessment than at later assessments, providing the largest sample size. This construct uses four levels of healthy aging: excellent, very good, good and other (not healthy aging). Every component used to create this definition had specific cut-points that needed to be met to attain each level of healthy aging, with these criteria decreasing in stringency as the levels of healthy aging decreased (e.g., 'excellent' healthy aging: MMSE $\geq$ 28, delayed word recall $\geq$ 7, independence in all 5 ADLs and 5 IADLs, and excellent self-rated function; 'very good' healthy aging: MMSE $\geq$ 26, delayed word recall $\geq$ 6, independence in all 5 ADLs, independence in $\geq$ 4 IADLs, and excellent or very good self-rated function; 'good' healthy aging: MMSE $\geq$ 24, delayed word recall $\geq$ 5, independence in $\geq$ 4 ADLs, independence in $\geq$ 3 IADLs, and excellent, very good, or good self-rated function; and lastly, participants were considered as not aging well if they were below any of the criteria for 'good' healthy aging). This definition had biological validity in terms of a very strong association found with longevity and all-cause mortality (Tyas

et al., 2007). It was created using data from the Nun Study, thus making it ideal for the current research study, which was also based on Nun Study data. The excellent, very good, and good categories were also collapsed to form an overall 'healthy aging' category vs. 'not healthy aging' category.

4.4.3 Covariates

In order to better understand the association between emotional expressivity in early adulthood and healthy aging, additional variables needed to be taken into account. As previously mentioned, the high level of homogeneity among participants greatly reduces or eliminates many potential confounders. Other potential confounders or effect modifiers, such as age at first cognitive assessment, age at the time the autobiography was written, *APOE*-ε4, educational attainment, idea density (the average number of ideas per ten words in the autobiographies), and grammatical complexity (classified according to eight levels ranging from 0 [simple one-clause sentences] to 7 [complex sentences]), were addressed through the use of multivariable adjustment (confounders) or stratification (effect modifiers) techniques in the various regression models (see description of multivariable analyses in section 4.5.2). It was hypothesized *a priori* that idea density would be an effect modifier based on previous evidence of effect modification of the association between emotional expressivity and another outcome, dementia, in the same data set (Morrison, 2015). Restriction was used as an additional technique to control for confounding whenever adjusting for confounders yielded non-viable results. Covariates with more than two levels (e.g., education) were combined as necessary based on descriptive analyses.

4.5 Analytic Strategy

All analyses were performed using SAS 9.4 statistical software (SAS Institute Inc., Cary, North Carolina). The Hosmer-Lemeshow goodness of fit test was used to assess the fit of each model for two-level healthy aging. For the four-level healthy aging outcome (multinomial models), this test was not available in SAS, and thus the fit of the multinomial models could not be verified, a limitation of current statistical software. Residual diagnostic assessments using DFBETA, C, and CBAR plots in PROC LOGISTIC were used to identify influential outliers (values greater than ±1.96) for two-level healthy aging, and no evidence of influential outliers was found. Testing for influential outliers using the four-level healthy aging outcome (multinomial models) was not available as an option in SAS at the time of analysis and thus could not be completed, reflecting an additional limitation of the current statistical software. The collinearity between exposure variables was examined using the PROC REG command in SAS. Multicollinearity of exposures and covariates was identified if two or more variance proportions were larger than 0.90 (with condition indices >30), or if the variance inflation factor was greater than 10 (Kleinbaum, Kupper, & Muller, 1988). No evidence of multicollinearity was found.

4.5.1 Descriptive Analyses

Univariate and bivariate statistics were computed for all variables to better understand and summarize the general characteristics of the analytic sample. Initial analyses included frequency tables and descriptive statistics (i.e., means, standard deviations). To assess the relationship between two categorical variables, Pearson chi-square tests were used when the sample sizes were large enough (i.e., cell counts greater than or equal to five). Otherwise, Fisher's exact tests were used if sample sizes were too small (i.e., cell counts less than five). T-tests were conducted to determine if an association existed between a continuous variable and a

dichotomous categorical variable. The Satterthwaite method was used in cases where the variances were unequal; otherwise, the pooled variance was used.

4.5.2 Multivariable Analyses

Binomial logistic regression models were used to analyze all research questions for the two-level healthy aging outcome. First-order interactions between each of the exposures and covariates were examined. Where significant interactions were found, the models were stratified by that covariate and re-tested for further effect modification in these stratified models. Firth logistic regression was used to address the issue of quasi-complete separation of data points, and is advantageous to use when sample sizes are small (SAS Institute Inc., 2018a), as is often the case for stratified models.

Multinomial logistic regression models were also created to address all research questions for the four-level healthy aging outcome. Alternatively, ordinal logistic regression could have been used instead of multinomial logistic regression. Ordinal logistic regression is typically used when the outcome variable is ordered, as was the case for the current study. Multinomial logistic regression is primarily employed when the dependent variable is nominal, but can also be used when the outcome is ordinal (SAS Institute Inc., 2018b). Multinomial logistic regression was preferred over ordinal logistic regression because it provided individual point estimates for each level of healthy aging. Having separate point estimates allowed for comparisons to be made across each level to determine if any patterns existed. Thus, multinomial logistic regression using the link=glogit command under PROC LOGISTIC was employed for every model to provide point estimates for each level of healthy aging (i.e., excellent, very good, and good).

Backward elimination was the primary technique used to determine the final models with the most appropriate subset of variables. This method is preferable to forward selection because the mean squared error is generally less for backward elimination than for forward selection techniques; a significance level of $\alpha=0.15$ for main effects and $\alpha=0.05$ for interaction terms was used as criteria for variable selection (Tyas et al., 2000). Sample size was not always sufficient for backward elimination due to quasi-complete separation of data points. In these instances, forward selection techniques were used. Where forward selection failed to run properly due to quasi-complete separation of data points, stepwise selection was used.

4.6 Ethics

Original ethics clearance for the Nun Study was obtained in 1990 from the University of Kentucky. This research project falls under the scope of a project approved by the Office of Research Ethics at the University of Waterloo (ORE #20174).

In order to ensure confidentiality, each participant in the Nun Study was randomly assigned an ID number instead of using their name. Any paper copies of Nun Study data are stored in locked cabinets at the University of Waterloo. Any electronic data from the Nun Study are stored on password-protected computers and are only accessible to research members who have signed a confidentiality agreement. Research members have restricted access to specific data subsets through shared drives on the research server that are password-protected.

Chapter 5

Results

5.1 Descriptive Analyses

5.1.1 Descriptive Results for Two-level Healthy Aging

Tables 1 and 2 summarize the descriptive results for the analytic sample where healthy aging was defined using two levels (n=149). Table 1 reflects the distribution of emotional expressivity (overall, positive and negative) with respect to the outcome of healthy aging, and Table 2 summarizes the participant characteristics of the analytic sample.

Of this sample, 108 (72.5%) participants were considered to be aging well, compared to 41 (27.5%) who were not aging well. Emotional expressivity, whether positive, negative, or combined ('overall'), did not significantly differ by healthy aging status (Table 1). Individuals aging well expressed a mean of 8.92 (7.61 positive and 1.31 negative) emotion words, whereas those not aging well expressed a mean of 8.44 (7.44 positive and 1.00 negative) emotion words. The median and range of emotion words was also quite wide for each group. Participants aging well expressed a median of 7.50 (0-32) (6.00 [0-23] positive and 1.00 [0-9] negative) emotion words, while those not aging well expressed a median of 4.00 (0-31) (4.00 [0-27] positive and 1.00 [0-4] negative) emotion words. Positive, negative and overall emotional expressivity were not significantly associated with healthy aging when assessed as quartiles or dichotomously. In general, those aging well were more likely to express higher overall emotions (26.85% vs. 14.63%), and higher positive emotions (28.70% vs. 19.51%) than those not aging well. In contrast, those aging well expressed relatively the same amount of higher negative emotions (88.89% vs. 85.37%) than participants not aging well.

Participants did not differ based on their age at first cognitive assessment, age at the time the autobiography was written, or level of education (Table 2). However, those aging well were less likely to have an apolipoprotein E-ε4 allele (18.52% vs. 46.34%, $p<0.01$), and more likely to have higher idea density (90.74% vs. 53.66%, $p<0.01$) and higher grammatical complexity (86.11% vs. 58.54%, $p<0.01$).

While testing for effect modification, an interaction was found between the exposures (overall and positive emotional expressivity) and level of education. No significant interactions were found for negative emotional expressivity, but descriptive analyses were completed for comparability purposes. In the Master's degree stratum (n=86), 65 (75.6%) were aging well, compared to 43 (68.3%) in the Bachelor's degree stratum (n=63) ($p=0.42$). Among those with a Master's degree or higher, participants aging well expressed significantly higher overall emotions (30.77% vs. 4.76%, $p<0.05$) and higher positive emotions (32.31% vs. 4.76%, $p<0.05$) (Table 3). There was no significant difference for either of these exposures and healthy aging status among those with a Bachelor's degree. *APOE*-ε4 status, idea density, and grammatical complexity all retained significance (either $p<0.05$ or $p<0.01$) for each of the strata, with the addition of age at the time the autobiography was written reaching significance ($p<0.05$) among those with a Bachelor's degree (Table 4).

Table 1. Emotional expressivity by two-level healthy aging status (n=149)

	Total (n=149)	Healthy Aging[1] Yes (n=108)	Healthy Aging[1] No (n=41)
Emotional Expressivity			
Raw Word Counts[2], Mean (SD)			
Overall	8.79 (7.39)	8.92 (7.25)	8.44 (7.84)
Positive	7.56 (6.30)	7.61 (6.03)	7.44 (7.05)
Negative	1.23 (1.65)	1.31 (1.77)	1.00 (1.28)
Raw Word Counts[2], Median (Range)			
Overall	7.00 (0-32)	7.50 (0-32)	4.00 (0-31)
Positive	6.00 (0-27)	6.00 (0-23)	4.00 (0-27)
Negative	1.00 (0-9)	1.00 (0-9)	1.00 (0-4)
Quartile Rankings, %			
Overall			
Quartile 1 (Low)	22.15	20.37	26.83
Quartile 2	24.16	22.22	29.27
Quartile 3	30.20	30.56	29.27
Quartile 4 (High)	23.49	26.85	14.63
Quartiles 1, 2 and 3 (Low)	76.51	73.15	85.37
Quartile 4 (High)	23.49	26.85	14.63
Positive			
Quartile 1 (Low)	24.83	22.22	31.71
Quartile 2	24.16	22.22	29.27
Quartile 3	24.83	26.85	19.51
Quartile 4 (High)	26.17	28.70	19.51
Quartiles 1, 2 and 3 (Low)	73.83	71.30	80.49
Quartile 4 (High)	26.17	28.70	19.51
Negative			
Quartile 1 (Low)	12.08	11.11	14.63
Quartile 2	41.61	38.89	48.78
Quartile 3	29.53	30.56	26.83
Quartile 4 (High)	16.78	19.44	9.76
Quartile 1 (Low)	12.08	11.11	14.63
Quartiles 2, 3 and 4 (High)	87.92	88.89	85.37

[1]Healthy aging level based on two categories.
[2]Coded from hand-written autobiographies with maximum length of one page.
Abbreviations: SD = standard deviation
Note: No measure of emotional expressivity significantly differed by healthy aging status.

Table 2. Participant characteristics by two-level healthy aging status (n=149)

	Total (n=149)	Healthy Aging[1] Yes (n=108)	Healthy Aging[1] No (n=41)
Characteristic			
Covariates			
Age at First Cognitive Assessment, Mean Years (SD)	79.99 (2.86)	79.78 (2.96)	80.56 (2.52)
Age at Autobiography[2], %			
Younger (< 25)	83.22	80.56	90.24
Older (≥ 25)	16.78	19.44	9.76
Level of Education, %			
Bachelor's Degree	42.28	39.81	48.78
≥Master's Degree	57.72	60.19	51.22
Presence of *APOE*-ε4, %			
No	73.83	81.48	53.66**
Yes	26.17	18.52	46.34
Idea Density, %			
Quartile 1 (Low)	19.46	9.26	46.34**
Quartile 2	24.83	25.00	24.39
Quartile 3	26.85	31.48	14.63
Quartile 4 (High)	28.86	34.26	14.63
Quartile 1 (Low)	19.46	9.26	46.34**
Quartiles 2, 3 and 4 (High)	80.54	90.74	53.66
Grammatical Complexity, %			
Quartile 1 (Low)	21.48	13.89	41.46**
Quartile 2	23.49	24.07	21.95
Quartile 3	28.86	32.41	19.51
Quartile 4 (High)	26.17	29.63	17.07
Quartile 1 (Low)	21.48	13.89	41.46**
Quartiles 2, 3 and 4 (High)	78.52	86.11	58.54

**p<0.01
[1]Healthy aging level based on two categories.
[2]Age at the time autobiography was written.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; SD = standard deviation

Table 3. Emotional expressivity by two-level healthy aging status, stratified by level of education (n=149)

	Level of Education					
	≥Master's Degree			Bachelor's Degree		
		Healthy Aging[1]			Healthy Aging	
	Total (n=86)	Yes (n=65)	No (n=21)	Total (n=63)	Yes (n=43)	No (n=20)
Emotional Expressivity						
Raw Word Counts[2], Mean (SD)						
Overall	8.66 (7.09)	9.18 (7.36)	7.05 (6.09)	8.97 (7.84)	8.53 (7.16)	9.90 (9.28)
Positive	7.38 (6.02)	7.83 (6.26)	6.00 (5.09)	7.81 (6.71)	7.28 (5.72)	8.95 (8.53)
Negative	1.28 (1.66)	1.35 (1.73)	1.05 (1.47)	1.16 (1.65)	1.26 (1.85)	0.95 (1.10)
Raw Word Counts[2], Median (Range)						
Overall	7.50 (0-29)	8.00 (0-29)	4.00 (0-19)	6.00 (0-32)	6.00 (0-32)	6.50 (0-31)
Positive	5.50 (0-22)	6.00 (0-22)	4.00 (0-16)	6.00 (0-27)	6.00 (0-23)	6.50 (0-27)
Negative	1.00 (0-7)	1.00 (0-7)	0.00 (0-4)	1.00 (0-9)	1.00 (0-9)	1.00 (0-4)
Quartile Rankings, %						
Overall						
Quartile 1 (Low)	24.42	21.54	33.33	19.05	18.60	20.00
Quartile 2	20.93	16.92	33.33	28.57	30.23	25.00
Quartile 3	30.23	30.77	28.57	30.16	30.23	30.00
Quartile 4 (High)	24.42	30.77	4.76	22.22	20.93	25.00
Quartiles 1, 2 and 3 (Low)	75.58	69.23	95.24*	77.78	79.07	75.00
Quartile 4 (High)	24.42	30.77	4.76	22.22	20.93	25.00

	Level of Education					
	≥Master's Degree			Bachelor's Degree		
		Healthy Aging[1]			Healthy Aging	
	Total (n=86)	Yes (n=65)	No (n=21)	Total (n=63)	Yes (n=43)	No (n=20)
Quartile Rankings (cont'd), %						
Positive						
Quartile 1 (Low)	25.58	21.54	38.10	23.81	23.26	25.00
Quartile 2	23.26	21.54	28.57	25.40	23.26	30.00
Quartile 3	25.58	24.62	28.57	23.81	30.23	10.00
Quartile 4 (High)	25.58	32.31	4.76	26.98	23.26	35.00
Quartiles 1, 2 and 3 (Low)	74.42	67.69	95.24*	73.02	76.74	65.00
Quartile 4 (High)	25.58	32.31	4.76	26.98	23.26	35.00
Negative						
Quartile 1 (Low)	12.79	9.23	23.81	11.11	13.95	5.00
Quartile 2	40.70	41.54	38.10	42.86	34.88	60.00
Quartile 3	26.74	26.15	28.57	33.33	37.21	25.00
Quartile 4 (High)	19.77	23.08	9.52	12.70	13.95	10.00
Quartile 1 (Low)	12.79	9.23	23.81	11.11	13.95	5.00
Quartiles 2, 3 and 4 (High)	87.21	90.77	76.19	88.89	86.05	95.00

*$p<0.05$

[1]Healthy aging level based on two categories.

[2]Coded from hand-written autobiographies with maximum length of one page.

Abbreviations: SD = standard deviation

Table 4. Participant characteristics by two-level healthy aging status, stratified by level of education (n=149)

	Level of Education					
	≥Master's Degree			Bachelor's Degree		
		Healthy Aging[1]			Healthy Aging	
	Total (n=86)	Yes (n=65)	No (n=21)	Total (n=63)	Yes (n=43)	No (n=20)
Characteristic						
Covariates						
Age at First Cognitive Assessment, Mean Years (SD)	79.68 (2.72)	79.45 (2.63)	80.37 (2.94)	80.42 (3.00)	80.27 (3.37)	80.75 (2.06)
Age at Autobiography[2], %						
Younger (< 25)	87.21	87.69	85.71	77.78	69.77	95.00*
Older (≥ 25)	12.79	12.31	14.29	22.22	30.23	5.00
Presence of *APOE*-ε4, %						
No	72.09	80.00	47.62**	76.19	83.72	60.00*
Yes	27.91	20.00	52.38	23.81	16.28	40.00
Idea Density, %						
Quartile 1 (Low)	16.28	7.69	42.86**	23.81	11.63	50.00**
Quartile 2	20.93	21.54	19.05	30.16	30.23	30.00
Quartile 3	29.07	32.31	19.05	23.81	30.23	10.00
Quartile 4 (High)	33.72	38.46	19.05	22.22	27.91	10.00
Quartile 1 (Low)	16.28	7.69	42.86**	23.81	11.63	50.00**
Quartiles 2, 3 and 4 (High)	83.72	92.31	57.14	76.19	88.37	50.00

	Level of Education					
	≥Master's Degree			Bachelor's Degree		
		Healthy Aging[1]			Healthy Aging	
	Total (n=86)	Yes (n=65)	No (n=21)	Total (n=63)	Yes (n=43)	No (n=20)
Grammatical Complexity, %						
Quartile 1 (Low)	18.60	10.77	42.86**	25.40	18.60	40.00**
Quartile 2	25.58	30.77	9.52	20.63	13.95	35.00
Quartile 3	32.56	32.31	33.33	23.81	32.56	5.00
Quartile 4 (High)	23.26	26.15	14.29	30.16	34.88	20.00
Quartile 1 (Low)	18.60	10.77	42.86**	25.40	18.60	40.00
Quartiles 2, 3 and 4 (High)	81.40	89.23	57.14	74.60	81.40	60.00

*p<0.05; **p<0.01

[1]Healthy aging level based on two categories.

[2]Age at the time autobiography was written.

Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; SD = standard deviation

5.1.2 Descriptive Results for Four-level Healthy Aging

Tables 5 and 6 summarize the descriptive results for the analytic sample where healthy aging was defined using four levels (n=149). Table 5 reflects the distribution of emotional expressivity (overall, positive and negative) with respect to the outcome of healthy aging, and Table 6 summarizes the participant characteristics of the analytic sample.

Participants experienced various levels of healthy aging which included 'excellent', 'very good', 'good', and 'not healthy aging.' Across the three exposures (overall, positive, and negative emotional expressivity), there was no significant difference by healthy aging status (Table 5). In general, a similar pattern can be observed across the four levels of healthy aging whereby, as the level of healthy aging increases, more positive emotions (defined as high vs. low) are expressed, as well as more overall emotions (defined as high vs. low). As was the case for two-level healthy aging, negative emotional expressivity remained relatively the same across each of the four levels. There was no significant effect modification when testing each of the exposures with the covariates, and thus no need to stratify the models for four-level healthy aging.

Participants did not differ based on their age at first cognitive assessment, age at the time the autobiography was written, or level of education (Table 6). However, those aging well were less likely to have an *APOE*-ε4 allele (21.88% (excellent), 16.98% (very good), 17.39% (good) vs. 46.34% (not aging well), $p<0.01$), and more likely to have higher idea density (90.63% (excellent), 96.23% (very good), 78.26% (good) vs. 53.66% (not aging well), $p<0.01$), and higher grammatical complexity (93.75% (excellent), 84.91% (very good), 78.26% (good) vs. 58.54% (not aging well), $p<0.01$).

Table 5. Emotional expressivity by four-level healthy aging status (n=149)

	Total (n=149)	Healthy Aging[1] Excellent (n=32)	Very Good (n=53)	Good (n=23)	Not HA (n=41)
Emotional Expressivity					
Raw Word Count[2], Mean (SD)					
Overall	8.79 (7.39)	8.34 (6.22)	9.62 (8.15)	8.13 (6.47)	8.44 (7.84)
Positive	7.56 (6.30)	7.25 (5.30)	8.15 (6.74)	6.87 (5.30)	7.44 (7.05)
Negative	1.23 (1.65)	1.09 (1.42)	1.47 (2.00)	1.26 (1.68)	1.00 (1.28)
Raw Word Count[2], Median (Range)					
Overall	7.00 (0-32)	8.50 (0-25)	6.00 (0-32)	8.00 (0-25)	4.00 (0-31)
Positive	6.00 (0-27)	6.00 (0-22)	5.00 (0-23)	7.00 (0-19)	4.00 (0-27)
Negative	1.00 (0-9)	1.00 (0-5)	1.00 (0-9)	1.00 (0-6)	1.00 (0-4)
Quartile Rankings, %					
Overall					
Quartile 1 (Low)	22.15	21.88	16.98	26.09	26.83
Quartile 2	24.16	21.88	20.75	26.09	29.27
Quartile 3	30.20	21.88	37.74	26.09	29.27
Quartile 4 (High)	23.49	34.38	24.53	21.74	14.63
Quartiles 1, 2 and 3 (Low)	76.51	65.63	75.47	78.26	85.37
Quartile 4 (High)	23.49	34.38	24.53	21.74	14.63
Positive					
Quartile 1 (Low)	24.83	25.00	18.87	26.09	31.71
Quartile 2	24.16	18.75	24.53	21.74	29.27
Quartile 3	24.83	21.88	30.19	26.09	19.51
Quartile 4 (High)	26.17	34.38	26.42	26.09	19.51
Quartiles 1, 2 and 3 (Low)	73.83	65.63	73.58	73.91	80.49
Quartile 4 (High)	26.17	34.38	26.42	26.09	19.51

		Healthy Aging[1]			
	Total (n=149)	Excellent (n=32)	Very Good (n=53)	Good (n=23)	Not HA (n=41)
Negative					
Quartile 1 (Low)	12.08	9.38	11.32	13.04	14.63
Quartile 2	41.61	46.88	35.85	34.78	48.78
Quartile 3	29.53	28.13	30.19	34.78	26.83
Quartile 4 (High)	16.78	15.63	22.64	17.39	9.76
Quartile 1 (Low)	12.08	9.38	11.32	13.04	14.63
Quartiles 2, 3 and 4 (High)	87.92	90.63	88.68	86.96	85.37

[1]Healthy aging level based on four categories.
[2]Coded from hand-written autobiographies with maximum length of one page.
Abbreviations: HA = healthy aging; SD = standard deviation
Note: No measure of emotional expressivity significantly differed by healthy aging status.

Table 6. Participant characteristics by four-level healthy aging status (n=149)

		Healthy Aging[1]			
	Total (n=149)	Excellent (n=32)	Very Good (n=53)	Good (n=23)	Not HA (n=41)
Characteristic					
Covariates					
Age at First Cognitive Assessment, Mean Years (SD)	79.99 (2.86)	79.52 (2.97)	79.52 (2.78)	80.74 (3.24)	80.56 (2.52)
Age at Autobiography[2], %					
Younger (< 25)	83.22	75.00	84.91	78.26	90.24
Older (≥ 25)	16.78	25.00	15.09	21.74	9.76
Level of Education, %					
Bachelor's Degree	42.28	34.38	39.62	47.83	48.78
≥Master's Degree	57.72	65.63	60.38	52.17	51.22
Presence of *APOE*-ε4, %					
No	73.83	78.13	83.02	82.61	53.66**
Yes	26.17	21.88	16.98	17.39	46.34
Idea Density, %					
Quartile 1 (Low)	19.46	9.38	3.77	21.74	46.34**
Quartile 2	24.83	18.75	22.64	39.13	24.39
Quartile 3	26.85	34.38	33.96	21.74	14.63
Quartile 4 (High)	28.86	37.50	39.62	17.39	14.63
Quartile 1 (Low)	19.46	9.38	3.77	21.74	46.34**
Quartiles 2, 3 and 4 (High)	80.54	90.63	96.23	78.26	53.66

	Total (n=149)	Healthy Aging[1] Excellent (n=32)	Very Good (n=53)	Good (n=23)	Not HA (n=41)
Grammatical Complexity, %					
Quartile 1 (low)	21.48	6.25	15.09	21.74	41.46**
Quartile 2	23.49	15.63	28.30	26.09	21.95
Quartile 3	28.86	31.25	33.96	30.43	19.51
Quartile 4 (High)	26.17	46.88	22.64	21.74	17.07
Quartile 1 (Low)	21.48	6.25	15.09	21.74	41.46**
Quartiles 2, 3 and 4 (High)	78.52	93.75	84.91	78.26	58.54

**p<0.01

[1]Healthy aging level based on four categories.

[2]Age at the time autobiography was written.

Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; HA = healthy aging; SD = standard deviation

5.2 Multivariable Analyses

5.2.1 Multivariable Results for Two-level Healthy Aging

To test the association between each of the exposures (overall, positive and negative emotional expressivity) in early adulthood and healthy aging status in late adulthood, binomial logistic regression was used. For overall and positive emotional expressivity, the models showed significant effect modification with education and were thus stratified by level of education (i.e., ≥Master's degree vs. Bachelor's degree). While stratification of negative emotional expressivity by educational strata and by positive emotional expressivity were considered for comparability with models of the other exposure variables, these analyses did not produce viable models. Thus, models of negative emotional expressivity were not stratified as negative emotional expressivity showed no significant interactions with any of the covariates. For comparability across all models, covariates were consistent across all final models, which were adjusted for age at first cognitive assessment (late adulthood), age at the time the autobiography was written (early adulthood), *APOE*-ε4 status, idea density, and grammatical complexity, with the addition of education for the negative emotional expressivity model. When testing the significance of the main effects, age at first cognitive assessment was consistently removed from the models. Removing this variable did not alter the significance of the results, and thus it was left in all final models for face validity and comparability with other studies. (For comparison of models with age at first cognitive assessment removed, please refer to Appendix C).

5.2.1.1 Research Question 1: Is overall emotional expressivity (positive and negative) in early adulthood associated with healthy aging?

Table 7 summarizes the odds ratios for the association between overall emotional expressivity and healthy aging, stratified by level of education (i.e., those with a Bachelor's degree). No significant odds ratios for overall emotional expressivity were found among this stratum, with all point estimates below one. The age at the time the autobiography was written (OR: 10.11, 95% CI, 1.68-128.13), and idea density (OR: 6.91, 95% CI: 1.65-39.03) were significantly and positively associated with healthy aging in the final model.

In contrast, Table 8 reports the results for the other educational stratum (i.e., those with a Master's degree or higher). In the crude model, as well as all adjusted and final models, the odds ratios for overall emotional expressivity remained highly significant. In the crude model, there was a greater than six-fold (OR: 6.16, 95% CI: 1.41-58.05) increase in the odds of healthy aging when individuals expressed more overall (positive and negative) emotions. When adjusted for all of the covariates in the final model, high overall emotional expressivity increased the odds of aging well by over twenty-fold (OR: 20.19, 95% CI: 2.09-681.26). In other words, among those with a Master's degree or higher, those aging well were 20 times more likely to express high overall emotions than people who were not aging well. High idea density (OR: 7.65, 95% CI: 1.74-41.38) and high grammatical complexity (OR: 9.21, 95% CI: 2.05-52.72) were also significantly and positively associated with healthy aging, whereas presence of *APOE*-ε4 (OR: 0.19, 95% CI: 0.05-0.71) was negatively associated, in comparison to those not aging well.

Table 7. The association between overall emotional expressivity and two-level healthy aging, stratified by level of education (Bachelor's degree) (n=63)

	Healthy Aging[1]						
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable							
Overall EE	0.78	0.80	0.78	0.74	0.69	0.57	0.51
High vs. Low[2]	(0.24-2.74)	(0.24-2.81)	(0.22-2.87)	(0.21-2.68)	(0.19-2.72)	(0.16-2.13)	(0.12-2.25)
Age at First Cognitive Assessment, Years		0.95 (0.80-1.13)					0.97 (0.76-1.23)
Age at Autobiography, Years			**5.63**				**10.11**
Older vs. Younger[3]			**(1.22-54.06)**				**(1.68-128.13)**
APOE-ε4				**0.31**			0.47
Presence vs. Absence				**(0.09-0.97)**			(0.11-2.03)
Idea Density					**6.90**		**6.91**
High vs. Low[4]					**(2.09-25.42)**		**(1.65-39.03)**
Grammatical Complexity						3.18	2.71
High vs. Low[4]						(0.97-10.92)	(0.62-12.78)

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table 8. The association between overall emotional expressivity and two-level healthy aging, stratified by level of education (≥Master's degree) (n=86)

	Healthy Aging[1]						
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable							
Overall EE *High vs. Low*[2]	**6.16** **(1.41-58.05)**	**5.68** **(1.30-53.48)**	**6.65** **(1.49-63.87)**	**8.70** **(1.80-87.78)**	**7.99** **(1.57-86.10)**	**10.76** **(2.03-120.20)**	**20.19** **(2.09-681.26)**
Age at First Cognitive Assessment, Years		0.90 (0.75-1.09)					0.92 (0.68-1.22)
Age at Autobiography, Years *Older vs. Younger*[3]			0.52 (0.12-2.50)				1.42 (0.15-21.19)
APOE-ε4 *Presence vs. Absence*				**0.18** **(0.06-0.54)**			**0.19** **(0.05-0.71)**
Idea Density *High vs. Low*[4]					**10.02** **(2.78-44.26)**		**7.65** **(1.74-41.38)**
Grammatical Complexity *High vs. Low*[4]						**9.33** **(2.60-41.46)**	**9.21** **(2.05-52.72)**

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

5.2.1.2 Research Question 2: Is positive emotional expressivity in early adulthood associated with a higher likelihood of healthy aging?

Tables 9 and 10 illustrate the impact positive emotional expressivity may have towards aging well. Similar to the results for overall emotional expressivity, positive emotional expressivity failed to reach significance for participants with a Bachelor's degree (Table 9). As in Table 7, age at the time the autobiography was written (OR: 9.58, 95% CI: 1.58-123.00), and idea density (OR: 7.34, 95% CI: 1.73-42.66) were both significant covariates in the final model.

Table 10 describes the association between positive emotional expressivity and healthy aging among those with a Master's degree or higher. A similar pattern is seen among these results as was described for overall emotional expressivity, with positive emotional expressivity consistently significant and positively associated with healthy aging. In the crude model, high positive emotional expressivity was associated with over a six-fold (OR: 6.60, 95% CI: 1.52-62.18) increase in healthy aging. When adjusted for all of the covariates, this value increased to over nineteen-fold (OR: 19.54, 95% CI: 2.15-631.96). Idea density (OR: 7.48, 95% CI: 1.71-40.02) and grammatical complexity (OR: 8.99, 95% CI: 2.02-50.91) were also positively associated with healthy aging in the final model, whereas *APOE*-ε4 status (OR: 0.20, 95% CI: 0.05-0.74) was negatively associated.

Table 9. The association between positive emotional expressivity and two-level healthy aging, stratified by level of education (Bachelor's degree) (n=63)

	Healthy Aging[1]						
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable							
Positive EE *High vs. Low*[2]	0.56 (0.18-1.78)	0.59 (0.19-1.88)	0.60 (0.18-1.97)	0.60 (0.19-1.97)	0.50 (0.14-1.76)	0.43 (0.13-1.43)	0.43 (0.10-1.76)
Age at First Cognitive Assessment, Years		0.96 (0.80-1.14)					0.99 (0.77-1.27)
Age at Autobiography, Years *Older vs. Younger*[3]			**5.51** **(1.19-53.11)**				**9.58** **(1.58-123.00)**
APOE-ε4 *Presence vs. Absence*				0.32 (0.10-1.02)			0.49 (0.11-2.17)
Idea Density *High vs. Low*[4]					**7.08** **(2.12-26.59)**		**7.34** **(1.73-42.66)**
Grammatical Complexity *High vs. Low*[4]						**3.41** **(1.03-11.91)**	3.02 (0.67-15.25)

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table 10. The association between positive emotional expressivity and two-level healthy aging, stratified by level of education (≥Master's degree) (n=86)

	Healthy Aging[1]						
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable							
Positive EE	**6.60**	**6.17**	**6.65**	**8.96**	**8.30**	**11.07**	**19.54**
High vs. Low[2]	**(1.52-62.18)**	**(1.42-58.04)**	**(1.53-62.55)**	**(1.87-89.86)**	**(1.65-88.53)**	**(2.11-122.50)**	**(2.15-631.96)**
Age at First Cognitive Assessment, Years		0.90 (0.75-1.08)					0.92 (0.68-1.21)
Age at Autobiography, Years			0.64				1.51
Older vs. Younger[3]			(0.16-2.99)				(0.19-21.76)
APOE-ε4				**0.18**			**0.20**
Presence vs. Absence				**(0.06-0.55)**			**(0.05-0.74)**
Idea Density					**9.89**		**7.48**
High vs. Low[4]					**(2.74-43.70)**		**(1.71-40.02)**
Grammatical Complexity						**9.19**	**8.99**
High vs. Low[4]						**(2.56-40.81)**	**(2.02-50.91)**

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

5.2.1.3 Research Question 3: Is negative emotional expressivity in early adulthood associated with a lower likelihood of healthy aging?

Throughout the crude, adjusted, and full models, negative emotional expressivity failed to reach significance (Table 11). Values stayed close to one, with confidence intervals including 1.00. Thus, there was no evidence of an association between expressing high negative emotions in early adulthood and not aging well in late adulthood. Other covariates that did reach significance for this model included age at the time the autobiography was written (OR: 7.14, 95% CI: 1.75-38.22), idea density (OR: 7.36, 95% CI: 2.69-22.37), and grammatical complexity (OR: 3.78, 95% CI: 1.42-10.31). *APOE*-ε4 status (OR: 0.39, 95% CI: 0.16-0.97) continued to remain negatively associated with healthy aging in the final model.

Table 11. The association between negative emotional expressivity and two-level healthy aging (n=149)

	Healthy Aging[1]							
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	Education	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable								
Negative EE	1.41	1.47	1.36	1.43	1.07	1.18	2.02	1.11
High vs. Low[2]	(0.48-3.84)	(0.50-4.01)	(0.46-3.69)	(0.49-3.89)	(0.34-3.07)	(0.35-3.58)	(0.66-5.79)	(0.30-3.76)
Age at First Cognitive Assessment, Years		0.91 (0.80-1.03)						0.88 (0.74-1.04)
Age at Autobiography, Years			2.02					**7.14**
Older vs. Younger[3]			(0.74-6.75)					**(1.75-38.22)**
Education				1.44				1.28
≥Master's Degree vs. Bachelor's Degree				(0.70-2.96)				(0.53-3.05)
APOE-ε4					**0.27**			**0.39**
Presence vs. Absence					**(0.12-0.59)**			**(0.16-0.97)**
Idea Density						**7.91**		**7.36**
High vs. Low[2]						**(3.36-19.59)**		**(2.69-22.37)**
Grammatical Complexity							**4.70**	**3.78**
High vs. Low[2]							**(2.05-11.04)**	**(1.42-10.31)**

[1]Healthy aging level based on two categories.
[2]High = top three quartiles; low = bottom quartile.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

5.2.2 Multivariable Results for Four-level Healthy Aging

To test the association between each of the exposures (overall, positive and negative emotional expressivity) in early adulthood and healthy aging status (as four levels) in late adulthood, an additional statistical technique, multinomial logistic regression, was performed. There was no effect modification between the exposures and the covariates. For comparability across all models, final models of all exposures were adjusted for the same covariates, and these were consistent with models for the two-level healthy aging outcome (age at first cognitive assessment, age at the time the autobiography was written, educational attainment, *APOE*-ε4 status, idea density, and grammatical complexity). While testing the significance of the main effects, much like the results found for two-level healthy aging, age at first cognitive assessment was consistently removed from the models. Removing this variable did not alter the significance of the results; therefore, it was kept in all final models for face validity and comparability with other studies. (For comparison of models with age at first cognitive assessment removed, please refer to Appendix D). Each of the three levels of healthy aging (excellent, very good, and good) was compared against the reference group of participants who were not aging well.

5.2.2.1 Research Question 1: Is overall emotional expressivity (positive and negative) in early adulthood associated with healthy aging (as four levels)?

To further understand the impact emotions expressed in early adulthood may have towards aging well, overall emotional expressivity was assessed using healthy aging as three levels (excellent, very good, and good) compared with the reference group of participants not aging well (Table 12). In the crude model, a pattern may be seen across the three levels of healthy aging. Moving from the 'good' level to the 'very good' level and on to the 'excellent' level shows a pattern in the odds ratios, whereby the point estimates get larger with each level (a pattern that is consistently shown in all remaining models). For the crude model, both the 'good' and 'very good' level of healthy aging failed to reach significance, but the 'excellent' level did. Those achieving an 'excellent' level of healthy aging were three times more likely to express high overall emotions than people not aging well (OR: 3.05, 95% CI: 1.01-10.04). This pattern was also observed when overall emotional expressivity was adjusted for *APOE*-ε4 status or idea density.

In both adjusted models, the odds ratios continued to get larger as the 'excellent' level of healthy aging was approached, whereby the odds ratios then reached significance (i.e., OR: 3.38, 95% CI: 1.09-11.51 (adjusted for *APOE*-ε4 status), and OR: 3.31, 95% CI: 1.01-11.96 (adjusted for idea density)). In the model adjusted for *APOE*-ε4 status, presence of *APOE*-ε4 was significantly and negatively associated with each level of healthy aging, while in the model adjusted for idea density, high idea density was significantly and positively associated with each level of healthy aging.

In the final model adjusted for all covariates, overall emotional expressivity failed to reach significance; however, the odds ratios did continue to show the same pattern of increase

moving from the lower level ‘good’ towards the higher level ‘excellent.’ In this final model, age at the time the autobiography was written, idea density and grammatical complexity showed strong and significant odds ratios for each of the ‘excellent’ and ‘very good’ levels of healthy aging.

Table 12. The association between overall emotional expressivity and four-level healthy aging (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Overall EE *High vs. Low*[2]	**3.05 (1.01-10.04)**	1.90 (0.67-5.89)	1.62 (0.42-6.11)
Model 2 (Age at First Cognitive Assessment)	Overall EE *High vs. Low*[2]	3.01 (0.99-9.95)	1.86 (0.65-5.84)	1.62 (0.42-6.12)
	Age at First Cognitive Assessment, Years	0.88 (0.74-1.04)	0.88 (0.75-1.02)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Overall EE *High vs. Low*[2]	2.87 (0.94-9.52)	1.86 (0.66-5.77)	1.54 (0.39-5.85)
	Age at Autobiography, Years *Older vs. Younger*[3]	2.84 (0.79-11.78)	1.58 (0.45-6.31)	2.50 (0.59-11.23)
Model 4 (Education)	Overall EE *High vs. Low*[2]	3.04 (1.00-10.03)	1.89 (0.67-5.88)	1.62 (0.42-6.11)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.80 (0.69-4.84)	1.45 (0.63-3.33)	1.04 (0.37-2.91)
Model 5 (*APOE*-ε4)	Overall EE *High vs. Low*[2]	**3.38 (1.09-11.51)**	2.13 (0.73-6.93)	1.82 (0.45-7.14)
	APOE-ε4 *Presence vs. Absence*	**0.30 (0.10-0.84)**	**0.23 (0.08-0.57)**	**0.24 (0.06-0.76)**
Model 6 (Idea Density)	Overall EE *High vs. Low*[2]	**3.31 (1.01-11.96)**	2.08 (0.66-7.32)	1.71 (0.43-6.69)
	Idea Density *High vs. Low*[4]	**8.73 (2.51-41.55)**	**22.56 (5.84-150.33)**	**3.16 (1.03-11.11)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 7 (Grammatical Complexity)	Overall EE *High vs. Low*[2]	2.99 (0.94-10.38)	1.87 (0.64-5.98)	1.60 (0.41-6.13)
	Grammatical Complexity *High vs. Low*[4]	**10.49 (2.62-71.02)**	**3.96 (1.53-11.04)**	2.54 (0.83-8.91)
Model 8 (Full)	Overall EE *High vs. Low*[2]	2.50 (0.69-9.96)	1.68 (0.51-6.17)	1.43 (0.34-5.87)
	Age at First Cognitive Assessment, Years	0.83 (0.66-1.04)	0.84 (0.69-1.03)	0.97 (0.78-1.22)
	Age at Autobiography, Years *Older vs. Younger*[3]	**18.99 (3.09-151.04)**	**8.58 (1.52-61.20)**	4.82 (0.78-34.08)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.83 (0.59-5.91)	1.32 (0.48-3.62)	1.01 (0.33-3.12)
	APOE-ε4 *Presence vs. Absence*	0.43 (0.12-1.47)	0.35 (0.11-1.04)	0.30 (0.07-1.03)
	Idea Density *High vs. Low*[4]	**12.91 (2.66-91.08)**	**21.96 (4.86-166.89)**	3.00 (0.86-12.15)
	Grammatical Complexity *High vs. Low*[4]	**11.30 (2.31-88.47)**	**3.64 (1.13-12.44)**	2.69 (0.78-10.69)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

5.2.2.2 Research Question 2: Is positive emotional expressivity in early adulthood associated with a higher likelihood of healthy aging (as four levels)?

When assessing the impact positive emotional expressivity in early adulthood may have towards a higher likelihood of healthy aging (as four levels), the exposure failed to reach significance throughout the crude, adjusted, and final models (Table 13). In the crude model, there was a similar pattern of increasing odds ratios to that found for overall emotional expressivity. Moving towards the 'excellent' level of healthy aging, the odds ratios continued to increase, suggesting that those who achieved an excellent level of healthy aging were more likely to express more positive emotion words in their autobiographies. When adjusted for *APOE*-ε4 status, presence of *APOE*-ε4 was significantly and negatively associated with each level of healthy aging, while in the model adjusted for idea density, high idea density was significantly and positively associated with each level of healthy aging.

In the final model adjusted for all covariates, high positive emotional expressivity did not reach significance (OR: 2.11, 95% CI: 0.62-7.71), but did show a similar dose-response to that found for the crude model. Age at the time the autobiography was written, idea density and grammatical complexity all showed significant and positive odds ratios in the final model for each of the 'excellent' and 'very good' levels of healthy aging.

Table 13. The association between positive emotional expressivity and four-level healthy aging (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Positive EE *High vs. Low*[2]	2.16 (0.75-6.44)	1.48 (0.56-4.11)	1.46 (0.42-4.88)
Model 2 (Age at First Cognitive Assessment)	Positive EE *High vs. Low*[2]	2.20 (0.76-6.64)	1.51 (0.57-4.24)	1.45 (0.42-4.87)
	Age at First Cognitive Assessment, Years	0.88 (0.73-1.03)	0.88 (0.75-1.01)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Positive EE *High vs. Low*[2]	2.16 (0.74-6.50)	1.48 (0.56-4.12)	1.45 (0.42-4.90)
	Age at Autobiography, Years *Older vs. Younger*[3]	3.08 (0.86-12.68)	1.64 (0.48-6.56)	2.57 (0.61-11.52)
Model 4 (Education)	Positive EE *High vs. Low*[2]	2.20 (0.76-6.62)	1.50 (0.57-4.18)	1.46 (0.42-4.89)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.86 (0.72-4.95)	1.47 (0.64-3.37)	1.05 (0.38-2.95)
Model 5 (*APOE*-ε4)	Positive EE *High vs. Low*[2]	2.46 (0.83-7.64)	1.72 (0.63-5.03)	1.69 (0.47-5.93)
	APOE-ε4 *Presence vs. Absence*	**0.30 (0.10-0.83)**	**0.23 (0.08-0.57)**	**0.23 (0.06-0.76)**
Model 6 (Idea Density)	Positive EE *High vs. Low*[2]	2.27 (0.74-7.35)	1.57 (0.54-4.88)	1.50 (0.42-5.22)
	Idea Density *High vs. Low*[4]	**8.52 (2.48-40.02)**	**22.25 (5.78-147.74)**	**3.14 (1.03-11.01)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 7 (Grammatical Complexity)	Positive EE *High vs. Low*[2]	2.08 (0.69-6.55)	1.44 (0.53-4.13)	1.43 (0.41-4.86)
	Grammatical Complexity *High vs. Low*[4]	**10.46 (2.64-70.50)**	**3.96 (1.53-10.99)**	2.53 (0.82-8.89)
Model 8 (Full)	Positive EE *High vs. Low*[2]	2.11 (0.62-7.71)	1.48 (0.48-4.95)	1.43 (0.38-5.35)
	Age at First Cognitive Assessment, Years	0.82 (0.65-1.02)	0.84 (0.68-1.03)	0.97 (0.77-1.21)
	Age at Autobiography, Years *Older vs. Younger*[3]	**20.98 (3.46-165.58)**	**8.92 (1.59-63.28)**	4.96 (0.81-34.84)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.88 (0.60-6.07)	1.34 (0.49-3.66)	1.02 (0.33-3.17)
	APOE-ε4 *Presence vs. Absence*	0.44 (0.12-1.49)	0.35 (0.11-1.04)	0.29 (0.07-1.02)
	Idea Density *High vs. Low*[4]	**12.68 (2.62-89.12)**	**21.62 (4.80-163.57)**	2.97 (0.85-12.04)
	Grammatical Complexity *High vs. Low*[4]	**10.99 (2.26-85.75)**	**3.57 (1.11-12.13)**	2.66 (0.77-10.52)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

5.2.2.3 Research Question 3: Is negative emotional expressivity in early adulthood associated with a lower likelihood of healthy aging (as four levels)?

Table 14 summarizes whether expressing more negative emotions in early adulthood was associated with a lower likelihood of healthy aging. Throughout the crude, adjusted, and final models, the exposure of negative emotional expressivity failed to reach significance. In the crude model, the odds ratios remained relatively close to one for each of the levels of healthy aging, and the confidence intervals included 1.00, indicating no significant associations. *APOE*-ε4 status and idea density continued to remain significant covariates in their adjusted models. Presence of *APOE*-ε4 was negatively associated with each of the healthy aging levels, whereas expressing a higher number of ideas was positively associated with each level of healthy aging.

Lastly, in the final model adjusted for all covariates, negative emotional expressivity stayed close to the value of one for the 'excellent' level (OR: 1.41, 95% CI: 0.26-8.78) and below one for the 'very good' (OR: 0.95, 95% CI: 0.20-4.24) and 'good' levels (OR: 0.84, 95% CI: 0.16-4.91), failing to reach significance in each case. Age at the time the autobiography was written, idea density and grammatical complexity continued to be strong covariates for inclusion in the model, showing significant and positive odds ratios for each of the 'excellent' and 'very good' levels of healthy aging.

Table 14. The association between negative emotional expressivity and four-level healthy aging (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Negative EE *High vs. Low*[2]	1.66 (0.40-8.39)	1.34 (0.39-4.64)	1.14 (0.27-5.88)
Model 2 (Age at First Cognitive Assessment)	Negative EE *High vs. Low*[2]	1.74 (0.42-8.89)	1.41 (0.41-4.93)	1.13 (0.26-5.82)
	Age at First Cognitive Assessment, Years	0.88 (0.74-1.03)	0.88 (0.75-1.01)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Negative EE *High vs. Low*[2]	1.55 (0.37-7.95)	1.31 (0.38-4.55)	1.09 (0.25-5.62)
	Age at Autobiography, Years *Older vs. Younger*[3]	3.02 (0.85-12.39)	1.62 (0.47-6.48)	2.56 (0.61-11.49)
Model 4 (Education)	Negative EE *High vs. Low*[2]	1.71 (0.41-8.70)	1.37 (0.40-4.75)	1.15 (0.27-5.89)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.84 (0.72-4.88)	1.46 (0.64-3.36)	1.04 (0.37-2.93)
Model 5 (*APOE*-ε4)	Negative EE *High vs. Low*[2]	1.30 (0.30-6.78)	0.99 (0.27-3.61)	0.84 (0.18-4.53)
	APOE-ε4 *Presence vs. Absence*	**0.33 (0.11-0.92)**	**0.24 (0.09-0.60)**	**0.24 (0.06-0.78)**
Model 6 (Idea Density)	Negative EE *High vs. Low*[2]	1.38 (0.30-7.49)	1.08 (0.26-4.25)	1.01 (0.23-5.37)
	Idea Density *High vs. Low*[2]	**8.21 (2.41-38.21)**	**21.92 (5.71-145.42)**	**3.11 (1.02-10.90)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 7 (Grammatical Complexity)	Negative EE *High vs. Low*[2]	2.60 (0.60-13.63)	1.92 (0.54-6.92)	1.51 (0.34-8.02)
	Grammatical Complexity *High vs. Low*[2]	**12.00 (2.99-81.39)**	**4.37 (1.66-12.40)**	2.72 (0.86-9.74)
Model 8 (Full)	Negative EE *High vs. Low*[2]	1.41 (0.26-8.78)	0.95 (0.20-4.24)	0.84 (0.16-4.91)
	Age at First Cognitive Assessment, Years	0.82 (0.65-1.02)	0.84 (0.68-1.02)	0.97 (0.78-1.21)
	Age at Autobiography, Years *Older vs. Younger*[3]	**21.99 (3.64-174.43)**	**9.38 (1.67-67.35)**	5.21 (0.85-37.06)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.80 (0.58-5.79)	1.32 (0.48-3.63)	1.00 (0.32-3.11)
	APOE-ε4 *Presence vs. Absence*	0.50 (0.14-1.71)	0.35 (0.11-1.08)	0.29 (0.07-1.03)
	Idea Density *High vs. Low*[2]	**12.19 (2.56-82.71)**	**22.66 (4.98-172.56)**	3.10 (0.88-12.74)
	Grammatical Complexity *High vs. Low*[2]	**11.33 (2.33-88.22)**	**3.57 (1.10-12.30)**	2.64 (0.75-10.61)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top three quartiles; low = bottom quartile.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Chapter 6

Discussion

The overall aim of this study was to investigate whether an association existed between emotional expressivity in early adulthood and healthy aging in late adulthood. In terms of the literature regarding emotions and health, past studies have largely focused on examining the association between emotions and longevity. In one study that used Nun Study data (Danner et. al., 2001), a very strong association was found between the number of positive emotions expressed in handwritten autobiographies and longevity nearly six decades later. Another study that also used Nun Study data found significant associations with the same emotional content from the autobiographies and risk of dementia (Morrison, 2015). These studies, as well as others previously discussed (e.g., Pressman & Cohen, 2012; Sin et al., 2015; Steptoe et al., 2008), provided the rationale for the current study.

Three research questions were used to explore this association. They included: 1) to determine if overall emotional expressivity (positive and negative) in early adulthood was associated with healthy aging, 2) to determine if positive emotional expressivity in early adulthood was associated with a higher likelihood of healthy aging, and 3) to determine if negative emotional expressivity in early adulthood was associated with a lower likelihood of healthy aging. Each of these questions was explored using a two-level and a four-level healthy aging outcome variable. It was hypothesized that an association would exist between overall emotional expressivity and healthy aging, and that a significant interaction with idea density would be found based on the findings from a previous study involving Nun Study emotions data (Morrison, 2015). It was also hypothesized that expressing more positive emotions in early adulthood would increase the likelihood of aging well, whereas expressing more negative

emotions would decrease this likelihood. Exploring these associations with a four-level healthy aging outcome variable provided the opportunity to examine a more nuanced definition of healthy aging to further clarify any potentially significant findings. Some caution is warranted when interpreting the results, especially for stratified results, or those using the four-level healthy aging outcome, as small sample sizes may have influenced the significance of the results, reflecting possible power issues.

6.1 Overall Findings

6.1.1 Overall Findings for Two-level Healthy Aging

In the initial descriptive analyses, chi-square tests revealed no significant associations between each of the emotion exposures and healthy aging. In terms of the covariates, *APOE*-ε4, idea density and grammatical complexity all had strong associations with healthy aging based on the chi-square tests. After stratification by educational attainment, chi-square tests revealed significant associations for overall and positive emotional expressivity with healthy aging among those with a Master's degree or higher. No significant associations were found for overall and positive emotional expressivity with healthy aging among participants with a Bachelor's degree. No significant interactions were found between negative emotional expressivity and the covariates, and thus there was no need to stratify the models. Negative emotional expressivity was not significantly associated with a lower likelihood of healthy aging. *APOE*-ε4 status, idea density and grammatical complexity all continued to be significantly associated with two-level healthy aging across each exposure.

Research question one focused on the association between overall emotional expressivity and healthy aging (two-level), while question two was developed to further understand the impact positive emotions may have towards healthy aging. Both exposures were significantly

associated with heathy aging. Indeed, among those who had attained at least a Master's degree or higher, expressing high overall or high positive emotions in the autobiographies led to a highly significant protective effect for aging well. Specifically, there was a twenty-fold increase in aging well when expressing high overall emotions or high positive emotions, adjusted for all of the covariates. These results are consistent with findings by Danner and colleagues (2001), whereby expressing more positive emotions in the autobiographies was associated with an increase in longevity. Additional studies have also consistently found significant associations between positive emotions and longevity. For example, in a separate study that also analyzed emotional expression in autobiographies, using more activated positive emotion words (e.g., active, energetic, and vigorous) was significantly associated with increased longevity (Pressman & Cohen, 2012). Additionally, a subjective well-being component, positive affect, was associated with longevity over the course of a 22 year-long study (Gana et al., 2016). Researchers Zhang and Han (2016) also found in a recent meta-analysis that having higher positive affect significantly lowered risk of mortality. Lastly, a non-verbal form of emotional expressivity, yearbook photographs, were studied to determine their relationship with life outcomes across adulthood (Harker & Keltner, 2001). Facial behaviour was coded from the photographs and characterized as positive emotional expressivity. This research found that positive emotional expressivity from the photographs predicted high scores of well-being (e.g., having better relationships with others and higher life satisfaction) in later adulthood.

There are no studies to my knowledge that have specifically focused on the association between emotional expressivity and healthy aging. Instead, studies have examined the association between positive affect and health behaviours (e.g., physical activity, sleep quality, medication adherence, alcohol use, and smoking status) (Sin et al., 2015) or health-related

psychosocial factors (e.g., social connectedness and optimism) (Steptoe et al., 2008). Both of these studies did in fact find significant associations between positive affect and their respective health outcomes, which strengthens the current findings of overall and positive emotional expressivity and the protective effect they have on aging well.

The broaden-and-build theory developed by Fredrickson (1998) helps elucidate the psychological benefit of positive affect. According to this theory, positive emotions, such as those analyzed from the autobiographies, may help build long-lasting physical, intellectual, social, and psychological resources (Fredrickson, 2001). In other words, more positive emotions, reflected in having a higher number of positive emotion words in the autobiographies, may have helped the participants to age more successfully. The physical, intellectual, social, and psychological resources can function as reserves and can be drawn upon to improve the chance of living longer (Fredrickson, 2004). Therefore, based on this theory, the use of more positive emotion words in the autobiographies for the current study may have provided a significant protective effect against cognitive decline, which contributed to healthier aging in later life.

The associations found for overall and positive emotional expressivity with healthy aging, although significant, had wide confidence intervals. This most likely occurred due to the stratified models having a smaller sample size, which has a tendency to widen confidence intervals, thereby reflecting lower precision. The large point estimates do clearly reflect strong associations between overall and positive emotional expressivity with healthy aging, however, and the models also showed good fit despite the lack of precision indicated by the wide confidence intervals. Thus, these findings do help strengthen the previous understanding of emotions and their impact on health, regardless of this limitation.

In terms of those with a Bachelor's degree, no significant associations were found between overall or positive emotional expressivity and healthy aging. It is possible that the restricted sample size of those with a Bachelor's degree decreased the power to achieve significant findings. The upper bound of the confidence intervals stayed close to two, possibly indicating that overall or positive emotional expressivity may also have a protective effect for aging well among those with a Bachelor's degree, although the results were not significant. This may also indicate that among those with a Bachelor's degree, the association was weaker than what was discovered among those with a Master's degree or higher, reflecting the strong effect of education on the association between emotional expressivity and healthy aging. In other words, the effect modification of education indicated a differential effect by stratum, whereby the level of educational attainment strongly impacted the association between emotional expressivity and healthy aging such that no significant associations between emotional expressivity and healthy aging were found among those with a Bachelor's degree, but instead, highly significant associations were only found among those with a Master's degree. The interactions with level of educational attainment may be partially attributed to the already strong influence higher levels of education have on aging well in later life (Sowa et al., 2016). Moreover, significant effect modification may have been found because the sample size for those aging well was larger when divided across two levels for the two-level healthy aging outcome, compared to being divided across four levels for the four-level healthy aging outcome, which would make data more sparse and reduce power and the ability for effect modification to be found.

Lastly, research question three explored the impact of negative emotional expressivity and the likelihood of aging well. No significant associations were discovered between expressing

negative emotions and lower likelihood of healthy aging. In the final model adjusted for all covariates, the point estimate remained close to one and the confidence intervals included one, indicating no significant association. These results are similar to what was discovered by Danner et al., (2001). In their research they found no statistically significant associations between negative emotional expressivity and risk of mortality. The number of negative emotions expressed in the autobiographies was quite low, which may account for the lack of significance in the current study.

In contrast to the broadening and building effect that positive emotions provide, negative emotions, such as sadness and anger, tend to narrow an individual's mindset or attention (Fredrickson, 2001; Fredrickson, 2004). Negative emotions may also lead to a great deal of problems for individuals and for society (Fredrickson, 1998). For example, anger might contribute to risk of heart disease or cancer, while fear and anxiety could lead to future anxiety disorders (Fredrickson 1998). Despite no significant findings between negative emotional expressivity and lower likelihood of healthy aging in the current study, negative emotions should continue to be explored in future studies as they may have implications towards aging well.

6.1.2 Overall Findings for Four-level Healthy Aging

To examine a more nuanced definition of healthy aging and further clarify the previous results of healthy aging as two levels, a four-level outcome measure of healthy aging was used. The same analytic sample of 149 participants (restricted by level of education) used for two-level healthy aging analyses was also used to determine significant associations between each of the exposures and four-level healthy aging.

The bivariate analyses yielded no significant associations. However, a trend, although not statistically significant, was found for overall and positive emotional expressivity. For both

measures, a pattern may be seen whereby as the level of healthy aging moved from those not aging well towards the excellent level, there was a continual increase in the amount of overall and positive emotions expressed in the autobiographies. In other words, those who achieved an excellent level of healthy aging expressed the highest number of overall and positive emotions. *APOE*-ε4 status, idea density and grammatical complexity all continued to be significant covariates with four-level healthy aging.

No effect modification was found across each exposure and the covariates, and thus there was no need to stratify these models. Research question one focused on the association between overall emotional expressivity and healthy aging (four-level), while question two continued to explore this relationship by focusing solely on positive emotions and their association with healthy aging. Based on the models created using multinomial logistic regression, a significant association was found. Specifically, in the crude model, those who achieved an excellent level of healthy aging were over three times as likely to express high overall (positive and negative) emotions than those not aging well. No statistically significant results were found across the crude, adjusted and final models involving positive emotional expressivity. For both exposures, moving down towards the 'very good' level and 'good' level, a dose-response was found whereby the lower the level of healthy aging, the lower the odds of expressing high overall or high positive emotions. In other words, the higher the level of healthy aging achieved, the greater the odds of expressing high overall or high positive emotions. This similar pattern was observed in all adjusted models. While these adjusted results were not significant, they still reflect a beneficial impact towards aging well. Having a larger sample to increase the power of the results would help strengthen these current findings.

Lastly, research question three focused on the association between negative emotional expressivity and healthy aging (four-level). Expressing high negative emotions was not found to significantly lower the likelihood of healthy aging across the crude, adjusted and final models. Similar to the results found using two-level healthy aging, the negative emotional expressivity measure did not reach statistical significance for associations with four-level healthy aging. The literature surrounding the association between negative emotions and healthy aging (as well as longevity) is quite sparse. In terms of their impact on longevity, negative emotional reactivity (Mroczek et al., 2013) and negative feelings (Xu & Roberts, 2010) were both found not to be significant predictors of mortality. However, negative affect was found to be associated with chronic stress and negative social support in a separate study (Steptoe et al., 2008). While this research did find a significant association, their focus was on health-related factors, which is not a direct measure of healthy aging. In the current study, when the final model was adjusted for all covariates, negative emotional expressivity was not significantly associated with each level of healthy aging, but for the 'good' and 'very good' levels, the point estimates did fall below one, indicating a possible lower likelihood of aging well. At the time the autobiographies were written, the participants expressed more positive emotions and fewer negative emotions, creating difficulty assessing the negative emotional expressivity measure. Future studies should include a larger sample where the participants may be more likely to express a greater range of positive or negative emotions in order to clarify the impact emotions have towards aging well.

6.1.3 Overall Findings Comparing Two and Four-level Healthy Aging

Significant associations were mainly found using the two-level healthy aging outcome, with a few statistically significant findings using the four-level healthy aging outcome. Results were similar to previous research regarding the association between emotions and longevity (see

section 2.3.3). However, while living a longer life may indicate good health, it does not necessarily equate to healthy aging. Exploring the associations using the four-level healthy aging measure was designed to clarify the significant results discovered from the two-level healthy aging analyses. Specifically, a significant interaction with level of education was no longer present when the exposures were assessed with healthy aging as four levels. The interactions found with level of education did not follow the *a priori* hypothesis that idea density would be a significant effect modifier based on previous Nun Study findings (Morrison, 2015). However, idea density did continue to be a highly significant covariate in all models using both the two and four-level healthy aging outcome, further strengthening its inclusion as a confounder in the current study. While overall and positive emotional expressivity were both found to be highly significant using the two-level healthy aging outcome, their confidence intervals were quite wide, indicating a sample size that may have been too small, reducing the precision of estimates. Lack of statistical significance across the four-level healthy aging models for each exposure also indicated that the sample size may have been too small, and also possibly indicated a lack of power needed to generate statistically significant results.

Overall, the findings from this current study found significant associations, but the interpretations are less clear. While emotional expressivity may act as an important factor for aging well, perhaps intellectual factors, such as idea density and grammatical complexity, may be more important. Across all three exposures for the two and four-level healthy aging models, idea density and grammatical complexity were consistently significant covariates. Both idea density and grammatical complexity were coded from the same autobiographies as emotional expressivity. Previous Nun Study findings have found that linguistic ability in early adulthood, namely idea density, had a very strong influence on longevity. Specifically, expressing one fewer

idea per ten words was associated with a 49% increase in mortality (Snowdon et al., 1999). Thus, it is possible that expressing more ideas and having a higher level of grammatical complexity in early adulthood may both be associated with aging well in later life.

Healthy aging can be impacted by any number of physical, cognitive or social factors throughout the course of one's life. Indeed, social determinants of health, such as income, education, employment, and social supports, may all reflect the importance of individual and community factors influencing how well individuals age. The life-course perspective is perhaps the most suitable model that helps elucidate the findings of the current study, as an exposure in early adulthood was found to significantly impact how well individuals were aging in late adulthood. This perspective is particularly interested in how the biological, psychosocial and behavioural pathways function across an individual's life, impacting the development of chronic conditions (Heikkinen, 2011), or in the case of the current study, impacting healthier aging outcomes. According to this perspective, the ability for individuals to age well may be strongly influenced by health-related factors (e.g., socio-economic status and housing) during critical life periods, such as childhood and early adulthood, and could be advantageous or disadvantageous for aging well in later life. While the present study did not have data on the exposures of interest (or other covariate data) collected across each participant's entire life, a difficulty with this model, this perspective still helps to elucidate the present findings by indicating that events in early adulthood can alter the course of one's life for better or worse. The findings from the current study indicate that emotions expressed in early adulthood do have an impact on how well we age; however, alternate early-adulthood predictors such as idea density and grammatical complexity may offer stronger support as intellectual factors which improve the likelihood of aging well.

6.2 Strengths

There were many strengths of this study assessing the association between emotional expressivity in early adulthood and healthy aging. The homogeneity of the sample was a great strength for this research project. The sample consisted of participants who were similar in terms of factors such as their lifestyle, marital status, religious views, access to health care, tobacco use, and alcohol consumption. These similarities helped decrease or eliminate many potential confounders typically present in other epidemiological studies.

Another strength was that both the coding system used to develop the exposures for emotional expressivity as well as the construct of healthy aging have been validated. Having access to the archival records was invaluable for assessing these associations. These records allowed researchers to create the unique exposure measure, emotional expressivity, for this study. Moreover, the written language skills, idea density and grammatical complexity, were also coded from the same autobiographies as emotional expressivity. This was a strength because it directly accounted for any impact these written language skills may have on emotional expressivity using the same source, thereby controlling for any additional confounding that idea density or grammatical complexity may have on the association between emotional expressivity and healthy aging. Additionally, since the written language skills and emotional expressivity were coded from the same source, this controls for other factors (e.g., personal or task-related factors or circumstances) that may have occurred at the time the autobiographies were written. Having access to the level of education attained by the participants was also a great strength, as significant interactions were found with overall and positive emotional expressivity, requiring stratification among the models using two-level healthy aging; in other words, these interactions

would not have been known without having data on this variable, and the current findings could have been dramatically different.

Assessing healthy aging as four levels provided the chance to examine a more comprehensive definition of healthy aging to further clarify any potentially significant findings. By assessing healthy aging as four levels, this study went beyond the standard two-level design (i.e., a simple healthy aging vs. not healthy aging dichotomy) found throughout the literature and used a more detailed four-level measure that helped describe the association between emotional expressivity and healthy aging more clearly. This four-level design was designed to elucidate the associations between emotional expressivity and specific levels of healthy aging instead of simply regarding everyone as aging well or not, as is the case in most healthy aging studies. The components used to define the healthy aging construct for the current study are also a strength in comparison to other healthy aging models. For example, the successful aging model by Rowe and Kahn (1997) focuses too heavily on the biomedical approach, thereby limiting the ability for older adults to be considered aging well, since this model requires individuals to remain disease free. In contrast, the healthy aging construct for the current study encompasses components from each of the biomedical, psychosocial, and lay perspectives, making it more acceptable for all individuals experiencing various degrees of health.

Existing literature has not directly focused on the association between emotional expressivity and healthy aging. The most comparable studies only focused on health behaviours and health-related psychosocial factors and these studies were cross-sectional in design. In contrast, the study design of Nun Study was a strength because it is longitudinal. This design allows researchers to study the association of factors in early life with outcomes in later life, thus maintaining temporality. Finding associations between emotional expressivity and healthy aging

nearly six decades later provides evidence that emotional expressivity may be considered as a predictor of healthy aging that is not only observable, but potentially modifiable in early adulthood. Additionally, intellectual factors such as idea density and grammatical complexity were found to be highly significant covariates and should be examined as other possible predictors of healthy aging in future research.

6.3 Limitations

Despite the many strengths associated with this research project, there were also some limitations that need to be addressed. One major limitation is the limited generalizability of the Nun Study data. This population differs from the general population in a number of ways. Firstly, the sample is entirely female, so inferences cannot be made regarding males. The sample is also quite homogenous, thus decreasing the generalizability of the findings.

Furthermore, the sample was also relatively small because of the limited number of scored autobiographies. Based on the selection criteria (i.e., autobiographies had to be handwritten, and participants had to be born in the United States and proficient in the English language), only 180 autobiographies were available for analysis. After including the covariates and restricting the sample by higher levels of education, the final analytic sample was reduced to 149 participants. This small sample size may have limited the statistical significance of the results that could have been achieved if the sample was larger (e.g., having more autobiographies for analysis).

The autobiographies were also written at a time when the sisters were about to take their final vows and may reflect greater use of words that express positive emotions, which decreased the ability to analyze negative emotional expressivity effectively. Indeed, the participants expressed very few negative emotions in their autobiographies, compared to the number of

positive emotions. Thus, negative emotional expressivity was required to be dichotomized differently than overall and positive emotional expressivity because of the lack of negative emotion words used in the autobiographies.

This study was also limited by focusing solely on emotions that individuals expressed. Participants may have had positive or negative emotions at the time they wrote the autobiographies, and simply did not express their emotions in their writing. Moreover, this study did not focus on specific discrete emotions. While discrete emotions may help to understand the specific emotions individuals are feeling, emotional expressivity reflects the overall effect of these emotions. Although emotional expressivity was the focus of this study, better understanding of the impact on healthy aging of both emotions and their expression provide an important contribution to emotion-related and health research.

There was also a lack of information regarding additional comorbidities and health conditions in this study. Information on vascular risk factors, for example, would have been helpful to include in the analyses as additional covariates that may have impacted the association between emotional expressivity and healthy aging.

Lastly, while the outcome of healthy aging used in this research project has been validated, there still lacks a consensual definition of healthy aging among researchers who focus on this topic. Thus, comparison of this study with others may be challenging.

6.4 Implications and Future Directions

This investigation enhanced current knowledge regarding emotions as well as healthy aging. Previous studies have found associations of emotions with longevity (Danner et al., 2001), health behaviours (Sin et al., 2015), and health-related psychosocial factors (Steptoe et al., 2008),

but no study specifically addressed the association of emotions with healthy aging. Thus, this was a gap in the literature that needed be explored, and the current study helped clarify that link.

The current findings build off of the aforementioned studies and support the inclusion of emotional expressivity as a novel predictor of healthy aging. In part, the broaden-and-build theory (Fredrickson, 1998) helps elucidate the significant associations found between positive emotional expressivity and healthy aging. Having more positive emotions in early adulthood may have helped broaden the participants' attentional scope, encouraging the development of connections and promoting global information processing (Fredrickson, 2004; Cameron, Bertenshaw, & Sheeran, 2015). Through this broadening experience, positive emotions may have then led to discovering new and imaginative actions, ideas, and social relationships, thereby building up their individual resources (physical, intellectual, social, and psychological) (Fredrickson, 2004). All of these resources work as reserves that can be drawn upon to increase one's chance of living longer (Fredrickson, 2004), or in the case of the current study, chance of aging well.

The findings from this study have numerous practical implications. Since previous research has not focused on the association between emotional expressivity and healthy aging, the current study provides the groundwork for future studies. Future research could focus on other verbal forms of emotional expression in autobiographies or other types of writing (e.g., posts on social media), as well as non-verbal forms of emotional expression (e.g., photographs) to further investigate emotional expressivity as a predictor of healthy aging.

Since the sample size was rather limited in the current study, future studies should aim to replicate these findings by using a larger sample. Moreover, the sample should also include male participants to determine if the associations change based on sex. Other opportunities for

advancing this area of study include having participants with different ethnic backgrounds and including other health conditions, such as cardiovascular disease, in the analyses.

It is also important to continue exploring healthy aging as four levels along with the standard two-level design, as it may help clarify significant findings. Future studies could use the healthy aging construct defined for this study so that more comparisons could be made between studies.

The associations found between emotional expressivity in early adulthood and healthy aging in late adulthood provide valuable evidence to support public health interventions that promote healthy aging. Having a better awareness of the effects of emotions in early life may contribute to healthier aging outcomes. In fact, this research could extend further to include assessing emotions at any point in one's life. The beneficial impact of positive emotions does not need to be restricted to just early adulthood; positive emotions may continue to impact all stages of life. Access to an online tool could be developed to assess the number of positive or negative emotion words from a sample of written text. For example, reflection journals or diaries during elementary and high school (i.e., critical early-life periods) may be appropriate sources of writing to analyze. Additionally, the tool could be used to analyze the positive or negative emotions expressed in individual photographs. Knowing this information may help people learn more about themselves and might encourage the use of more positive emotions or fewer negative emotions after assessment. Moreover, the findings of this research could be disseminated to the public through online websites, or by facilitators of healthy aging programs, and both options may help inspire changes in emotional expression. Possible interventions could include community engagement programs whereby facilitators could discuss the key findings of the current study, and participants could be assessed to determine whether they are expressing more

positive or negative emotions in their photographs, for example. After assessment, facilitators could create various physical, cognitive, and social activities with a greater emphasis on maximizing the number of positive emotions. For example, the model developed by Baltes and Baltes (1997) could serve as a guide to structure these activities for people of different ages, informing participants how best to select appropriate goals, optimize resources, and compensate for age-related and time restrictions. Overall, these activities may encourage the expression of more positive emotions, or fewer negative emotions, and this may lead to a greater number of people in the population experiencing improved healthy aging. With this increase in the number of people aging well, this may have a direct impact on reducing health-related care in older age, and also reducing the cost for society to support individuals into old age. In conclusion, the emotions expressed in early adulthood not only impact how long we live, but may also offer a modifiable way to promote healthy aging in late adulthood, and thereby increase the quality of life for anyone entering old age.

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Appendix

Appendix A: Literature Search Strategies

Table A1. Literature search strategy: PubMed

	Search Strategy #1		
Database	**Emotional Expressivity**	**Late Life**	**Healthy Aging**
PubMed/Medline	Expressed Emotion [MeSH] OR Emotions [MeSH] OR Affect [MeSH] OR Positive Emotion [all fields] OR Positive Emotions [all fields] OR Negative Emotion [all fields] OR Negative Emotions [all fields]	Aged [MeSH] OR Aging [MeSH] OR Older Adult [all fields] OR Later Life [all fields] OR Life Outcomes [all fields] OR Elderly [all fields] OR Seniors [all fields]	Longevity [MeSH] OR Healthy Aging [MeSH] OR Healthy Aging [all fields] OR Healthy Ageing [all fields] OR Successful Aging [all fields] OR Successful Ageing [all fields] OR Aging Well [all fields] OR Ageing Well [all fields]

Overall Search Strategy: #**1** AND #**2** AND #**3**
(Retrieved 302 records)

#**3** Longevity [MeSH] OR Healthy Aging [MeSH] OR Healthy Aging [all fields] OR Healthy Ageing [all fields] OR Successful Aging [all fields] OR Successful Ageing [all fields] OR Aging Well [all fields] OR Ageing Well [all fields]
#**2** Aged [MeSH] OR Aging [MeSH] OR Older Adult [all fields] OR Later Life [all fields] OR Life Outcomes [all fields] OR Elderly [all fields] OR Seniors [all fields]
#**1** Expressed Emotion [MeSH] OR Emotions [MeSH] OR Affect [MeSH] OR Positive Emotion [all fields] OR Positive Emotions [all fields] OR Negative Emotion [all fields] OR Negative Emotions [all fields]

Table A2. Literature search strategy: PsycINFO

	Search Strategy #2		
Concept	**Emotional Expressivity**	**Late Life**	**Healthy Aging**
Author Keyword	Emotional Expressivity Emotional Expression Emotion	Aged Later life Elderly	Healthy Aging Healthy Ageing Successful Aging Successful Ageing Aging Well Ageing Well
Subject Headings Index Terms	Affective Valence Emotional Content Emotional Responses Emotional States Emotionality	Aging Geriatrics	Longevity

Overall Search Strategy: #**1** AND #**2** AND #**3**
(Retrieved 237 records)

#**3** "Healthy Aging" OR "Healthy Ageing" OR "Successful Aging" OR "Successful Ageing" OR "Aging Well" OR "Ageing Well" OR "Longevity"
#**2** "Aged" OR "Later Life" OR "Elderly" OR "Aging" OR "Geriatrics"
#**1** "Emotional Expressivity" OR "Emotional Expression" OR "Emotion" OR "Affective Valence" OR "Emotional Content" OR "Emotional Responses" OR "Emotional States" OR "Emotionality"

Appendix B: Literature Summary Table

Table B1. Summary of findings focused on the association between emotional expressivity and healthy aging

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Cameron et al., 2015 The impact of positive affect on health cognitions and behaviours: a meta-analysis of the experimental evidence	Meta-analysis found 39 articles with 54 independent tests of the impact of positive affect on health cognitions and behaviour Majority of sample included US university students (age not reported) Inclusion criteria: experimental studies only, and studies had to measure health cognitions or behaviours	*Exposure*: Used studies that manipulated (e.g., lasting 10-15 minutes) positive affect (e.g., film clips, and music) *Covariates*: Not mentioned Created seven pathways (e.g., improved attention, increased motivation) to assess the association between positive affect and health cognitions and behaviours	Health cognitions (e.g., measures of intention, perceived behavioural control, outcome expectancies, risk perceptions, cravings, and message reception) and behaviours (e.g., food consumption, general health goals, smoking, alcohol consumption, and physical activity)	Used unbiased effect size estimator Cohen's *d* (e.g., small effect size $d = 0.20$, medium effect size $d = 0.50$, and large effect size $d = 0.80$) with 95% confidence intervals	No overall impact of positive affect on health cognitions or behaviours was found A single effect was found between positive affect and physical activity Caution is warranted when interpreting results because of the small number of under-powered studies and publication bias

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Danner et al., 2001 Positive emotions in early life and longevity: findings from the Nun Study	180 Catholic nuns from the School Sisters of Notre Dame Autobiographies written between ages 18-32 (mean = 22) Age of survival ranged from 75-95 (76 died after one year of follow-up)	*Exposure*: Handwritten autobiographies scored for emotional content *Covariates*: Idea density, grammatical complexity, age, education	All-cause mortality	Cox proportional hazard regression Relative risk of death	Strong inverse association found between positive emotional content and risk of mortality
Gana et al., 2016 Subjective wellbeing and longevity: findings from a 22-year cohort study	Used the PAQUID database Used data from 10 follow-up periods Started with 3777 (baseline age: 62-101, 58% female) at time 1 and ended with 364 (71% female) at time 10 (22 years later)	*Exposure*: Subjective well-being components (i.e., life satisfaction, positive affect, negative affect) *Covariates*: Age, gender, education, mean arterial pressure, diabetes mellitus, hypercholesterolemia, dementia, functional status, self-rated health	All-cause mortality	Discrete time-survival analysis	Positive affect was independently associated with longevity even in the presence of other covariates

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Mroczek et al., 2013 Emotional reactivity and mortality: longitudinal findings from the VA Normative Aging Study	An 8-day daily diary conducted in 2002 on 181 men aged 58-88 from the Veteran Affairs Normative Aging Study 10-year follow-up (35 people died)	*Exposure*: Emotional reactivity for both positive and negative affect *Covariates*: Age, daily stressors, daily physical symptoms, bodily pain, neuroticism and extraversion	All-cause mortality	Cox proportional hazard ratios	Larger decreases in daily positive affect in response to daily stressors were associated with more than a doubling in mortality risk over almost a decade of follow-up
Pressman et al., 2005 (Review) Does positive affect influence health?	Various study populations and sample characteristics were mentioned throughout the review	*Exposure*: Positive affect defined as the feelings that suggest a level of enjoyable engagement with the environment *Covariates*: Various covariates were mentioned (e.g., age, sex, socioeconomic status)	Markers of physical health status: focused on studies of morbidity, mortality, survival, and indicators of disease progression and severity	Studies were generally prospective and experimental	The review did not unequivocally indicate that positive affect is beneficial for health, but suggests a more differentiated view of when positive affect may have positive, negative, or no effects

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Pressman et al., 2012 Positive emotion word use and longevity in famous deceased psychologists	The sample included 88 influential researchers born between 1843 and 1926, primarily male and entirely White who wrote an autobiography Lived an average of 79 years, were 66.7 at the age of publication of autobiography, and lived on average 12.3 years post-publication of autobiography	*Exposure*: Percent of emotional words used was calculated and categorized by valence (positive or negative) and arousal (activated or not activated) *Covariates*: Optimism, social integration, sex, year of birth, health, language, and age at time of publication	Longevity, which was defined as the number of days between the date of birth and date of death	Multiple logistic regression	The use of more activated positive emotional words was associated with increased longevity (controlling for sex, year of birth, language, year of publication and health)

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Sin et al., 2015 Positive affect and health behaviours across 5 years in patients with coronary heart disease: The Heart and Soul Study	Outpatients with CHD from The Heart and Soul Study at baseline (N = 1022), and 5 years later at follow up (N = 662) Sample included mainly males in their mid to late sixties	*Exposure*: Positive affect measured using a 10-item subscale of the PANAS *Covariates*: Demographics, cardiac disease severity, and depressive symptoms	Health behaviours: physical activity, sleep quality, medication adherence, alcohol use, and smoking	t-tests, chi square tests, linear regression, logistic regression	At baseline, higher positive affect was associated with better physical activity, sleep quality, medical adherence, and non-smoking Increases in positive affect after 5 years co-occurred with improvements in physical activity, sleep quality, and medical adherence
Steptoe et al., 2008 Positive affect and psychosocial processes related to health	Participants included 716 men and women aged 58-72 who were members of the Whitehall II cohort Exposure data collected over 1 day	*Exposure*: Positive and negative affect measured by the ecological momentary assessment (EMA) *Covariates*: height and weight (BMI), gender, age, smoking	Health-related psychosocial factors: socio-economic status (education, occupation, income), marital status, social isolation, social support, neighbourhood stress, financial strain, depression, psychological distress, optimism, psychological coping	t-tests, chi square tests, repeated measures ANOVA, Tukey's least significant differences, ANCOVA, regression	Positive affect was associated with social connectedness, social support, optimism, adaptive coping Negative affect was associated with chronic stress, negative social support, maladaptive coping

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Xu et al., 2010 The power of positive emotions: it's a matter of life or death – subjective well-being and longevity over 28 years in a general population	Included data from the Alameda County Study over 28 years (N = 6856), adult population of all ages Exposure variables were chosen from baseline data	*Exposure*: Subjective well-being (positive feelings, domain life satisfaction, positive affect, negative feelings) *Covariates*: Age, sex, years of education, baseline health status, perceived health, and social network	Longevity, measured by all-cause, natural-cause, and unnatural-cause mortality	Sequential cox proportional hazard models	Subjective well-being, positive feelings, and domain life satisfaction was associated with lowered risks of all-cause mortality Negative feelings showed no associations with mortality outcomes

Study	Study Population, Sample Characteristics	Exposure and Covariates	Outcome	Analysis	Results
Zhang et al., 2016 Positive affect and mortality risk in older adults: a meta-analysis	A quantitative systematic review was conducted to examine the association between positive affect and mortality outcomes in healthy community-dwelling older adults (55 years and older) Sample sizes ranged from 101 to 97,253. Age of participants ranged from 12 to 92 years (mean = 58) 22 studies were included in data analysis	*Exposure*: Positive affect *Covariates*: Various covariates were mentioned (e.g., education, age, and sex)	Mortality risk in older adults (55 years and older)	Used effect size estimates: hazard ratios, odds ratios, and relative risks	Higher positive affect was associated with lower mortality risk in community-dwelling older adults, even after controlling for medical, psychological, and social factors

Appendix C: Additional Multivariable Models using Two-Level Healthy Aging

Table C1. The association between overall emotional expressivity and two-level healthy aging, stratified by level of education (Bachelor's degree), with age at first cognitive assessment removed (n=63)

	Healthy Aging[1]							
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable								
Overall EE	0.78	0.80	0.78	0.74	0.69	0.57	0.51	0.50
High vs. Low[2]	(0.24-2.74)	(0.24-2.81)	(0.22-2.87)	(0.21-2.68)	(0.19-2.72)	(0.16-2.13)	(0.12-2.25)	(0.12-2.14)
Age at First Cognitive Assessment, Years		0.95 (0.80-1.13)					0.97 (0.76-1.23)	Removed
Age at Autobiography, Years			**5.63**				**10.11**	**10.30**
Older vs. Younger[3]			**(1.22-54.06)**				**(1.68-128.13)**	**(1.73-140.02)**
APOE-ε4				**0.31**			0.47	0.45
Presence vs. Absence				**(0.09-0.97)**			(0.11-2.03)	(0.10-1.97)
Idea Density					**6.90**		**6.91**	**7.27**
High vs. Low[4]					**(2.09-25.42)**		**(1.65-39.03)**	**(1.72-41.67)**
Grammatical Complexity						3.18	2.71	2.94
High vs. Low[4]						(0.97-10.92)	(0.62-12.78)	(0.71-12.88)

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table C2. The association between overall emotional expressivity and two-level healthy aging, stratified by level of education (≥Master's degree), with age at first cognitive assessment removed (n=86)

	Healthy Aging[1]							
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable								
Overall EE *High vs. Low*[2]	**6.16 (1.41-58.05)**	**5.68 (1.30-53.48)**	**6.65 (1.49-63.87)**	**8.70 (1.80-87.78)**	**7.99 (1.57-86.10)**	**10.76 (2.03-120.20)**	**20.19 (2.09-681.26)**	**26.68 (2.97-865.78)**
Age at First Cognitive Assessment, Years		0.90 (0.75-1.09)					0.92 (0.68-1.22)	Removed
Age at Autobiography, Years *Older vs. Younger*[3]			0.52 (0.12-2.50)				1.42 (0.15-21.19)	0.95 (0.17-6.04)
APOE-ε4 *Presence vs. Absence*				**0.18 (0.06-0.54)**			**0.19 (0.05-0.71)**	**0.17 (0.04-0.64)**
Idea Density *High vs. Low*[4]					**10.02 (2.78-44.26)**		**7.65 (1.74-41.38)**	**8.28 (1.82-46.42)**
Grammatical Complexity *High vs. Low*[4]						**9.33 (2.60-41.46)**	**9.21 (2.05-52.72)**	**9.94 (2.16-58.08)**

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table C3. The association between positive emotional expressivity and two-level healthy aging, stratified by level of education (Bachelor's degree), with age at first cognitive assessment removed (n=63)

	Healthy Aging[1]							
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable								
Positive EE *High vs. Low*[2]	0.56 (0.18-1.78)	0.59 (0.19-1.88)	0.60 (0.18-1.97)	0.60 (0.19-1.97)	0.50 (0.14-1.76)	0.43 (0.13-1.43)	0.43 (0.10-1.76)	0.42 (0.10-1.66)
Age at First Cognitive Assessment, Years		0.96 (0.80-1.14)					0.99 (0.77-1.27)	Removed
Age at Autobiography, Years *Older vs. Younger*[3]			**5.51 (1.19-53.11)**				**9.58 (1.58-123.00)**	**10.13 (1.69-137.96)**
APOE-ε4 *Presence vs. Absence*				0.32 (0.10-1.02)			0.49 (0.11-2.17)	0.48 (0.11-2.11)
Idea Density *High vs. Low*[4]					**7.08 (2.12-26.59)**		**7.34 (1.73-42.66)**	**7.63 (1.78-44.73)**
Grammatical Complexity *High vs. Low*[4]						**3.41 (1.03-11.91)**	3.02 (0.67-15.25)	3.14 (0.74-14.37)

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table C4. The association between positive emotional expressivity and two-level healthy aging, stratified by level of education (≥Master's degree), with age at first cognitive assessment removed (n=86)

	Healthy Aging[1]							
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable								
Positive EE *High vs. Low*[2]	**6.60 (1.52-62.18)**	**6.17 (1.42-58.04)**	**6.65 (1.53-62.55)**	**8.96 (1.87-89.86)**	**8.30 (1.65-88.53)**	**11.07 (2.11-122.50)**	**19.54 (2.15-631.96)**	**25.89 (2.98-810.52)**
Age at First Cognitive Assessment, Years		0.90 (0.75-1.08)					0.92 (0.68-1.21)	Removed
Age at Autobiography, Years *Older vs. Younger*[3]			0.64 (0.16-2.99)				1.51 (0.19-21.76)	1.02 (0.19-6.27)
APOE-ε4 *Presence vs. Absence*				**0.18 (0.06-0.55)**			**0.20 (0.05-0.74)**	**0.17 (0.04-0.65)**
Idea Density *High vs. Low*[4]					**9.89 (2.74-43.70)**		**7.48 (1.71-40.02)**	**8.21 (1.82-45.63)**
Grammatical Complexity *High vs. Low*[4]						**9.19 (2.56-40.81)**	**8.99 (2.02-50.91)**	**9.86 (2.16-57.10)**

[1]Healthy aging level based on two categories.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table C5. The association between negative emotional expressivity and two-level healthy aging, with age at first cognitive assessment removed (n=149)

	Healthy Aging[1]								
	Crude Model	Age at First Cognitive Assessment	Age at Autobiography	Education	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable									
Negative EE *High vs. Low*[2]	1.41 (0.48-3.84)	1.47 (0.50-4.01)	1.36 (0.46-3.69)	1.43 (0.49-3.89)	1.07 (0.34-3.07)	1.18 (0.35-3.58)	2.02 (0.66-5.79)	1.11 (0.30-3.76)	1.17 (0.31-3.91)
Age at First Cognitive Assessment, Years		0.91 (0.80-1.03)						0.88 (0.74-1.04)	Removed
Age at Autobiography, Years *Older vs. Younger*[3]			2.02 (0.74-6.75)					**7.14 (1.75-38.22)**	**4.56 (1.32-20.82)**
Education ≥*Master's Degree vs. Bachelor's Degree*				1.44 (0.70-2.96)				1.28 (0.53-3.05)	1.41 (0.60-3.30)
APOE-ε4 *Presence vs. Absence*					**0.27 (0.12-0.59)**			**0.39 (0.16-0.97)**	**0.37 (0.15-0.91)**
Idea Density *High vs. Low*[2]						**7.91 (3.36-19.59)**		**7.36 (2.69-22.37)**	**7.40 (2.70-22.41)**

Healthy Aging[1]

	Crude Model	Age at Assessment	Age at Autobiography	Education	*APOE*-ε4	Idea Density	Grammatical Complexity	Full Model	Revised Model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Variable									
Grammatical Complexity *High vs. Low*[2]							**4.70 (2.05-11.04)**	**3.78 (1.42-10.31)**	**4.15 (1.56-11.37)**

[1]Healthy aging level based on two categories.
[2]High = top three quartiles; low = bottom quartile.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Appendix D: Additional Multivariable Models using Four-level Healthy Aging

Table D1. The association between overall emotional expressivity and four-level healthy aging, with age at first cognitive assessment removed (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Overall EE *High vs. Low*[2]	**3.05 (1.01-10.04)**	1.90 (0.67-5.89)	1.62 (0.42-6.11)
Model 2 (Age at First Cognitive Assessment)	Overall EE *High vs. Low*[2]	3.01 (0.99-9.95)	1.86 (0.65-5.84)	1.62 (0.42-6.12)
	Age at First Cognitive Assessment, Years	0.88 (0.74-1.04)	0.88 (0.75-1.02)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Overall EE *High vs. Low*[2]	2.87 (0.94-9.52)	1.86 (0.66-5.77)	1.54 (0.39-5.85)
	Age at Autobiography, Years *Older vs. Younger*[3]	2.84 (0.79-11.78)	1.58 (0.45-6.31)	2.50 (0.59-11.23)
Model 4 (Education)	Overall EE *High vs. Low*[2]	3.04 (1.00-10.03)	1.89 (0.67-5.88)	1.62 (0.42-6.11)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.80 (0.69-4.84)	1.45 (0.63-3.33)	1.04 (0.37-2.91)
Model 5 (*APOE*-ε4)	Overall EE *High vs. Low*[2]	**3.38 (1.09-11.51)**	2.13 (0.73-6.93)	1.82 (0.45-7.14)
	APOE-ε4 *Presence vs. Absence*	**0.30 (0.10-0.84)**	**0.23 (0.08-0.57)**	**0.24 (0.06-0.76)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 6 (Idea Density)	Overall EE *High vs. Low*[2]	**3.31 (1.01-11.96)**	2.08 (0.66-7.32)	1.71 (0.43-6.69)
	Idea Density *High vs. Low*[4]	**8.73 (2.51-41.55)**	**22.56 (5.84-150.33)**	**3.16 (1.03-11.11)**
Model 7 (Grammatical Complexity)	Overall EE *High vs. Low*[2]	2.99 (0.94-10.38)	1.87 (0.64-5.98)	1.60 (0.41-6.13)
	Grammatical Complexity *High vs. Low*[4]	**10.49 (2.62-71.02)**	**3.96 (1.53-11.04)**	2.54 (0.83-8.91)
Model 8 (Full)	Overall EE *High vs. Low*[2]	2.50 (0.69-9.96)	1.68 (0.51-6.17)	1.43 (0.34-5.87)
	Age at First Cognitive Assessment, Years	0.83 (0.66-1.04)	0.84 (0.69-1.03)	0.97 (0.78-1.22)
	Age at Autobiography, Years *Older vs. Younger*[3]	**18.99 (3.09-151.04)**	**8.58 (1.52-61.20)**	4.82 (0.78-34.08)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.83 (0.59-5.91)	1.32 (0.48-3.62)	1.01 (0.33-3.12)
	APOE-ε4 *Presence vs. Absence*	0.43 (0.12-1.47)	0.35 (0.11-1.04)	0.30 (0.07-1.03)
	Idea Density *High vs. Low*[4]	**12.91 (2.66-91.08)**	**21.96 (4.86-166.89)**	3.00 (0.86-12.15)
	Grammatical Complexity *High vs. Low*[4]	**11.30 (2.31-88.47)**	**3.64 (1.13-12.44)**	2.69 (0.78-10.69)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 9 (Revised Model)	Overall EE *High vs. Low*[2]	2.91 (0.82-11.46)	1.89 (0.58-6.92)	1.50 (0.36-6.19)
	Age at First Cognitive Assessment, Years	Removed	Removed	Removed
	Age at Autobiography, Years *Older vs. Younger*[3]	**9.82 (1.98-62.18)**	4.49 (0.98-25.92)	4.16 (0.84-23.91)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.91 (0.62-6.04)	1.38 (0.51-3.72)	1.06 (0.35-3.27)
	APOE-ε4 *Presence vs. Absence*	0.38 (0.11-1.26)	0.31 (0.10-1.26)	0.30 (0.07-1.03)
	Idea Density *High vs. Low*[4]	**12.70 (2.71-84.44)**	**22.05 (4.91-165.49)**	2.99 (0.85-12.19)
	Grammatical Complexity *High vs. Low*[4]	**13.57 (2.80-105.95)**	**4.17 (1.32-14.09)**	2.57 (0.75-9.98)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table D2. The association between positive emotional expressivity and four-level healthy aging, with age at first cognitive assessment removed (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Positive EE *High vs. Low*[2]	2.16 (0.75-6.44)	1.48 (0.56-4.11)	1.46 (0.42-4.88)
Model 2 (Age at First Cognitive Assessment)	Positive EE *High vs. Low*[2]	2.20 (0.76-6.64)	1.51 (0.57-4.24)	1.45 (0.42-4.87)
	Age at First Cognitive Assessment, Years	0.88 (0.73-1.03)	0.88 (0.75-1.01)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Positive EE *High vs. Low*[2]	2.16 (0.74-6.50)	1.48 (0.56-4.12)	1.45 (0.42-4.90)
	Age at Autobiography, Years *Older vs. Younger*[3]	3.08 (0.86-12.68)	1.64 (0.48-6.56)	2.57 (0.61-11.52)
Model 4 (Education)	Positive EE *High vs. Low*[2]	2.20 (0.76-6.62)	1.50 (0.57-4.18)	1.46 (0.42-4.89)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.86 (0.72-4.95)	1.47 (0.64-3.37)	1.05 (0.38-2.95)
Model 5 (*APOE*-ε4)	Positive EE *High vs. Low*[2]	2.46 (0.83-7.64)	1.72 (0.63-5.03)	1.69 (0.47-5.93)
	APOE-ε4 *Presence vs. Absence*	**0.30 (0.10-0.83)**	**0.23 (0.08-0.57)**	**0.23 (0.06-0.76)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 6 (Idea Density)	Positive EE *High vs. Low*[2]	2.27 (0.74-7.35)	1.57 (0.54-4.88)	1.50 (0.42-5.22)
	Idea Density *High vs. Low*[4]	**8.52 (2.48-40.02)**	**22.25 (5.78-147.74)**	**3.14 (1.03-11.01)**
Model 7 (Grammatical Complexity)	Positive EE *High vs. Low*[2]	2.08 (0.69-6.55)	1.44 (0.53-4.13)	1.43 (0.41-4.86)
	Grammatical Complexity *High vs. Low*[4]	**10.46 (2.64-70.50)**	**3.96 (1.53-10.99)**	2.53 (0.82-8.89)
Model 8 (Full)	Positive EE *High vs. Low*[2]	2.11 (0.62-7.71)	1.48 (0.48-4.95)	1.43 (0.38-5.35)
	Age at First Cognitive Assessment, Years	0.82 (0.65-1.02)	0.84 (0.68-1.03)	0.97 (0.77-1.21)
	Age at Autobiography, Years *Older vs. Younger*[3]	**20.98 (3.46-165.58)**	**8.92 (1.59-63.28)**	4.96 (0.81-34.84)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.88 (0.60-6.07)	1.34 (0.49-3.66)	1.02 (0.33-3.17)
	APOE-ε4 *Presence vs. Absence*	0.44 (0.12-1.49)	0.35 (0.11-1.04)	0.29 (0.07-1.02)
	Idea Density *High vs. Low*[4]	**12.68 (2.62-89.12)**	**21.62 (4.80-163.57)**	2.97 (0.85-12.04)
	Grammatical Complexity *High vs. Low*[4]	**10.99 (2.26-85.75)**	**3.57 (1.11-12.13)**	2.66 (0.77-10.52)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 9 (Revised Model)	Positive EE			
	High vs. Low[2]	2.29 (0.68-8.23)	1.55 (0.51-5.15)	1.47 (0.39-5.50)
	Age at First Cognitive Assessment, Years	Removed	Removed	Removed
	Age at Autobiography, Years			
	Older vs. Younger[3]	**10.53 (2.15-66.35)**	**4.57 (1.01-26.35)**	4.23 (0.86-24.19)
	Education			
	≥Master's Degree vs. Bachelor's Degree	1.98 (0.65-6.26)	1.41 (0.53-3.79)	1.08 (0.35-3.32)
	APOE-ε4			
	Presence vs. Absence	0.38 (0.11-1.27)	**0.31 (0.10-0.92)**	0.29 (0.07-1.02)
	Idea Density			
	High vs. Low[4]	**12.27 (2.65-80.55)**	**21.50 (4.83-160.06)**	2.97 (0.84-12.08)
	Grammatical Complexity			
	High vs. Low[4]	**13.32 (2.76-103.92)**	**4.08 (1.30-13.68)**	2.54 (0.75-9.82)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top quartile; low = bottom three quartiles.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
[4]High = top three quartiles; low = bottom quartile.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Table D3. The association between negative emotional expressivity and four-level healthy aging, with age at first cognitive assessment removed (n=149)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 1 (Crude)	Negative EE *High vs. Low*[2]	1.66 (0.40-8.39)	1.34 (0.39-4.64)	1.14 (0.27-5.88)
Model 2 (Age at First Cognitive Assessment)	Negative EE *High vs. Low*[2]	1.74 (0.42-8.89)	1.41 (0.41-4.93)	1.13 (0.26-5.82)
	Age at First Cognitive Assessment, Years	0.88 (0.74-1.03)	0.88 (0.75-1.01)	1.02 (0.86-1.21)
Model 3 (Age at Autobiography)	Negative EE *High vs. Low*[2]	1.55 (0.37-7.95)	1.31 (0.38-4.55)	1.09 (0.25-5.62)
	Age at Autobiography, Years *Older vs. Younger*[3]	3.02 (0.85-12.39)	1.62 (0.47-6.48)	2.56 (0.61-11.49)
Model 4 (Education)	Negative EE *High vs. Low*[2]	1.71 (0.41-8.70)	1.37 (0.40-4.75)	1.15 (0.27-5.89)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.84 (0.72-4.88)	1.46 (0.64-3.36)	1.04 (0.37-2.93)
Model 5 (*APOE*-ε4)	Negative EE *High vs. Low*[2]	1.30 (0.30-6.78)	0.99 (0.27-3.61)	0.84 (0.18-4.53)
	APOE-ε4 *Presence vs. Absence*	**0.33 (0.11-0.92)**	**0.24 (0.09-0.60)**	**0.24 (0.06-0.78)**

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 6 (Idea Density)	Negative EE *High vs. Low*[2]	1.38 (0.30-7.49)	1.08 (0.26-4.25)	1.01 (0.23-5.37)
	Idea Density *High vs. Low*[2]	**8.21 (2.41-38.21)**	**21.92 (5.71-145.42)**	**3.11 (1.02-10.90)**
Model 7 (Grammatical Complexity)	Negative EE *High vs. Low*[2]	2.60 (0.60-13.63)	1.92 (0.54-6.92)	1.51 (0.34-8.02)
	Grammatical Complexity *High vs. Low*[2]	**12.00 (2.99-81.39)**	**4.37 (1.66-12.40)**	2.72 (0.86-9.74)
Model 8 (Full)	Negative EE *High vs. Low*[2]	1.41 (0.26-8.78)	0.95 (0.20-4.24)	0.84 (0.16-4.91)
	Age at First Cognitive Assessment, Years	0.82 (0.65-1.02)	0.84 (0.68-1.02)	0.97 (0.78-1.21)
	Age at Autobiography, Years *Older vs. Younger*[3]	**21.99 (3.64-174.43)**	**9.38 (1.67-67.35)**	5.21 (0.85-37.06)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.80 (0.58-5.79)	1.32 (0.48-3.63)	1.00 (0.32-3.11)
	APOE-ε4 *Presence vs. Absence*	0.50 (0.14-1.71)	0.35 (0.11-1.08)	0.29 (0.07-1.03)
	Idea Density *High vs. Low*[2]	**12.19 (2.56-82.71)**	**22.66 (4.98-172.56)**	3.10 (0.88-12.74)
	Grammatical Complexity *High vs. Low*[2]	**11.33 (2.33-88.22)**	**3.57 (1.10-12.30)**	2.64 (0.75-10.61)

		Healthy Aging[1]		
Model	**Variable**	Excellent OR (95% CI)	Very Good OR (95% CI)	Good OR (95% CI)
Model 9 (Revised Model)	Negative EE *High vs. Low*[2]	1.52 (0.28-9.23)	1.02 (0.22-4.49)	0.89 (0.17-5.19)
	Age at First Cognitive Assessment, Years	Removed	Removed	Removed
	Age at Autobiography, Years *Older vs. Younger*[3]	**10.88 (2.20-69.53)**	**4.84 (1.05-28.58)**	4.53 (0.91-26.50)
	Education *≥Master's Degree vs. Bachelor's Degree*	1.92 (0.63-6.00)	1.42 (0.53-3.82)	1.09 (0.36-3.34)
	APOE-ε4 *Presence vs. Absence*	0.44 (0.12-1.46)	**0.32 (0.10-0.97)**	0.30 (0.07-1.05)
	Idea Density *High vs. Low*[2]	**11.66 (2.56-74.62)**	**21.84 (4.89-162.87)**	3.05 (0.86-12.52)
	Grammatical Complexity *High vs. Low*[2]	**13.93 (2.87-108.85)**	**4.12 (1.29-14.02)**	2.53 (0.72-9.94)

[1]Healthy aging level based on four categories; reference category = not healthy aging.
[2]High = top three quartiles; low = bottom quartile.
[3]Age at the time autobiography was written: older ≥ 25; younger < 25.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; CI = confidence interval; EE = emotional expressivity; OR = odds ratio

Appendix E: Assessment of Selection Bias in the Analytic Sample

To analyze the association between emotional expressivity in early adulthood and healthy aging in late adulthood, various exclusions were required to create the analytic sample. The original Nun Study population consisted of 678 individuals; however, the emotional expressivity data were only available for 180 participants. Thus, individuals who did have emotional expressivity data (n=180) were compared to those without emotional expressivity data (n=498) (Table E1). Of the 180 individuals with complete data on emotional expressivity, 164 were not missing any data on covariates. Therefore, non-response analysis was performed on those in the initial healthy aging sample (n=164) compared to those who were removed due to missing data (n=16) (Table E2). The initial healthy aging sample (n=164) was further restricted by level of education because of quasi-complete separation of data points during multivariable analyses. After restriction to those with a Bachelor's degree or higher, 149 participants remained in the analytic sample. These individuals were compared to those who were excluded from the original sample with complete data on emotional expressivity (n=31) (Table E3), and to those excluded based solely on level of education (n=15) (Table E4).

When the total autobiography sample (n=180) was compared to those who were excluded from the original Nun Study data (n=498), there were significant differences in terms of the participants' age at first cognitive assessment, age at the time the autobiography was written, level of education, and healthy aging status (Table E1). Individuals from the total autobiography sample (n=180) were significantly younger at first cognitive assessment (80.19 vs. 84.41, $p<0.01$), and more likely to be older (≥ 25) at the time the autobiography was written ($p<0.01$), to have attained a higher level of education ($p<0.01$), and to have aged well in later life ($p<0.01$).

A significant difference was also noticed when comparing the initial healthy aging sample (n=164) to those excluded from the total autobiography sample (n=16) due to missing data on *APOE*-ε4 (Table E2). Specifically, individuals from the initial healthy aging sample (n=164) were more likely to have higher levels of idea density compared to those missing data on *APOE*-ε4 ($p<0.05$). In other words, these participants were more likely to have a higher number of ideas per ten words in the autobiographies compared to those who were excluded based on missing data.

The final healthy aging sample (n=149) was compared to those who were excluded based on missing data or who attained lower levels of education (n=31) (Table E3). These individuals differed significantly in terms of their level of education ($p<0.01$), idea density ($p<0.01$), and healthy aging status ($p<0.01$). Specifically, the participants in the final healthy aging sample (n=149) were more likely to have attained higher levels of education, have higher idea density, and were more likely to have aged well. These results were not surprising, as individuals in the final healthy aging sample only included those who were highly educated, and higher levels of educational attainment were expected to contribute to better healthy aging.

Lastly, participants in the final healthy aging sample (n=149) were compared to those who were excluded based solely on their level of education (n=15) (Table E4). These individuals were significantly more likely to have attained higher levels of education ($p<0.01$), express a greater number of ideas in the autobiographies ($p<0.01$), have higher levels of grammatical complexity ($p<0.01$), and were more likely to have aged well ($p<0.01$). These findings were also not surprising, as being highly educated may allow individuals to express a greater number of ideas, and construct more complex grammatical sentences, which in turn may lead to greater chances of aging well.

Overall, the non-response bias analyses yielded significant differences between the various samples. It is important to consider these selection bias analyses when interpreting the results for the current study; however, the significant differences are fairly understandable and it was necessary to create the final analytic samples in order to achieve viable models during multivariable analyses.

Table E1. Descriptive statistics of total autobiography sample compared to excluded participants

	Total Nun Study Sample (n=678)	Total Autobiography Sample (n=180)	Excluded Participants from Total Sample (n=498)
Characteristic			
Age at First Cognitive Assessment, Mean Years (SD)	83.29 (5.47)	80.19 (3.03)	84.41 (5.71)**
Age at Autobiography[1], %			
Younger (< 25)	76.99	84.44	47.83**
Older (≥ 25)	23.01	15.56	52.17
Education			
≤ High School	15.49	8.89	17.87**
Bachelor's Degree	39.82	38.33	40.36
≥Master's Degree	44.69	52.78	41.77
Presence of *APOE*-ε4, %			
No	77.22	73.17	78.68
Yes	22.78	26.83	21.32
Healthy Aging, %			
No	47.93	33.89	53.02**
Yes	52.07	66.11	46.98
Healthy Aging, %			
No	47.93	33.89	53.02**
Good	15.24	15.00	15.32
Very Good	25.89	32.22	23.59
Excellent	10.59	18.89	8.06

**p<0.01
[1]Age at the time autobiography was written.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; SD = standard deviation
Note:
For the total Nun Study sample, n=226 had complete data for age at autobiography.
For the excluded participants sample, n=46 had complete data for age at autobiography.
For the total Nun Study sample, n=619 had complete data for presence of *APOE*-ε4.
For the total autobiography sample, n=164 had complete data for presence of *APOE*-ε4.
For the excluded participants sample, n=455 had complete data for presence of *APOE*-ε4.
For the total Nun Study sample, n=676 had complete data for healthy aging.
For the excluded participants sample, n=496 had complete data for healthy aging.

Table E2. Descriptive statistics of initial healthy aging sample compared to excluded participants missing covariate data

	Total Autobiography Sample (n=180)	Initial Healthy Aging Sample (n=164)	Excluded Participants from Total Sample (n=16)
Characteristic			
Age at First Cognitive Assessment, Mean Years (SD)	80.19 (3.03)	80.16 (3.05)	80.44 (2.89)
Age at Autobiography[1], %			
Younger (< 25)	84.44	82.93	100.00
Older (≥ 25)	15.56	17.07	0.00
Education			
≤ High School	8.89	9.15	6.25
Bachelor's Degree	38.33	38.41	37.50
≥Master's Degree	52.78	52.44	56.25
Idea Density, %			
Quartile 1 (Low)	25.00	22.56	50.00*
Quartiles 2, 3 and 4 (High)	75.00	77.44	50.00
Grammatical Complexity			
Quartile 1 (Low)	24.44	25.00	18.75
Quartiles 2, 3 and 4 (High)	75.56	75.00	81.25
Overall EE			
Quartiles 1, 2 and 3 (Low)	76.67	77.44	68.75
Quartile 4 (High)	23.33	22.56	31.25
Positive EE			
Quartiles 1, 2 and 3 (Low)	73.89	75.00	62.50
Quartile 4 (High)	26.11	25.00	37.50
Negative EE			
Quartile 1 (Low)	11.11	11.59	6.25
Quartiles 2, 3 and 4 (High)	88.89	88.41	93.75
Healthy Aging, %			
No	33.89	32.32	50.00
Yes	66.11	67.68	50.00

	Total Autobiography Sample	Initial Healthy Aging Sample	Excluded Participants from Total Sample
	(n=180)	(n=164)	(n=16)
Healthy Aging, %			
No	33.89	32.32	50.00
Good	15.00	15.24	12.50
Very Good	32.22	32.93	25.00
Excellent	18.89	19.51	12.50

*p<0.05
[1]Age at the time autobiography was written.
Abbreviations: EE = emotional expressivity; SD = standard deviation

Table E3. Descriptive statistics of final healthy aging sample compared to excluded participants missing covariate data or who were restricted by level of education

Characteristic	Total Autobiography Sample (n=180)	Final Healthy Aging Sample (n=149)	Excluded Participants from Total Sample (n=31)
Age at First Cognitive Assessment, Mean Years (SD)	80.19 (3.03)	79.99 (2.86)	81.13 (3.65)
Age at Autobiography[1], %			
Younger (< 25)	84.44	83.22	90.32
Older (≥ 25)	15.56	16.78	9.68
Education			
≤ High School	8.89	0.00	51.61**
Bachelor's Degree	38.33	42.28	19.35
≥Master's Degree	52.78	57.72	29.03
Presence of *APOE*-ε4, %			
No	73.17	73.83	66.67
Yes	26.83	26.17	33.33
Idea Density, %			
Quartile 1 (Low)	25.00	19.46	51.61**
Quartiles 2, 3 and 4 (High)	75.00	80.54	48.39
Grammatical Complexity			
Quartile 1 (Low)	24.44	21.48	38.71
Quartiles 2, 3 and 4 (High)	75.56	78.52	61.29
Overall EE			
Quartiles 1, 2 and 3 (Low)	76.67	76.51	77.42
Quartile 4 (High)	23.33	23.49	22.58
Positive EE			
Quartiles 1, 2 and 3 (Low)	73.89	73.83	74.19
Quartile 4 (High)	26.11	26.17	25.81
Negative EE			
Quartile 1 (Low)	11.11	12.08	6.45
Quartiles 2, 3 and 4 (High)	88.89	87.92	93.55
Healthy Aging, %			
No	33.89	27.52	64.52**
Yes	66.11	72.48	35.48

	Total Autobiography Sample	Final Healthy Aging Sample	Excluded Participants from Total Sample
	(n=180)	(n=149)	(n=31)
Healthy Aging, %			
No	33.89	27.52	64.52**
Good	15.00	15.44	12.90
Very Good	32.22	35.57	16.13
Excellent	18.89	21.48	6.45

**p<0.01

[1]Age at the time autobiography was written.

Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; EE = emotional expressivity; SD = standard deviation

Note:

For the excluded participants sample, n=15 had complete data for presence of *APOE*-ε4.

Table E4. Descriptive statistics of final healthy aging sample compared to excluded participants from the initial healthy aging sample based on restriction by level of education

	Initial Healthy Aging Sample (n=164)	Final Healthy Aging Sample (n=149)	Excluded Participants from Initial Sample (n=15)
Characteristic			
Age at First Cognitive Assessment, Mean Years (SD)	80.16 (3.05)	79.99 (2.86)	81.86 (4.30)
Age at Autobiography[1], %			
Younger (< 25)	82.93	83.22	80.00
Older (≥ 25)	17.07	16.78	20.00
Education			
≤ High School	9.15	0.00	100.00**
Bachelor's Degree	38.41	42.28	0.00
≥Master's Degree	52.44	57.72	0.00
Presence of *APOE*-ε4, %			
No	73.17	73.83	66.67
Yes	26.83	26.17	33.33
Idea Density, %			
Quartile 1 (Low)	22.56	19.46	53.33**
Quartiles 2, 3 and 4 (High)	77.44	80.54	46.67
Grammatical Complexity			
Quartile 1 (Low)	25.00	21.48	60.00**
Quartiles 2, 3 and 4 (High)	75.00	78.52	40.00
Overall EE			
Quartiles 1, 2 and 3 (Low)	77.44	76.51	86.67
Quartile 4 (High)	22.56	23.49	13.33
Positive EE			
Quartiles 1, 2 and 3 (Low)	75.00	73.83	86.67
Quartile 4 (High)	25.00	26.17	13.33
Negative EE			
Quartile 1 (Low)	11.59	12.08	6.67
Quartiles 2, 3 and 4 (High)	88.41	87.92	93.33
Healthy Aging, %			
No	32.32	27.52	80.00**
Yes	67.68	72.48	20.00

	Initial Healthy Aging Sample	Final Healthy Aging Sample	Excluded Participants from Initial Sample
	(n=164)	(n=149)	(n=15)
Healthy Aging, %			
No	32.32	27.52	80.00**
Good	15.24	15.44	13.33
Very Good	32.93	35.57	6.67
Excellent	19.51	21.48	0.00

**p<0.01
[1]Age at the time autobiography was written.
Abbreviations: *APOE*-ε4 = apolipoprotein E-ε4 allele; EE = emotional expressivity; SD = standard deviation