Investigating Interactions Between Executive Functions and Quality of Life in Older Adults

by

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B.A., York University, 2011
M.Sc., University of Victoria, 2013

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Supervisory Committee

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Abstract

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The cognitive aging literature contains abundant evidence of the natural vulnerability of the frontal areas of the brain and the associated impact on higher-order cognition. Namely, Executive Functions (EFs) have been repeatedly shown to decline steadily after 60 (Schaie, 2013). These age-related changes are said to impact most aspects of everyday life including quality of life (QoL; Davis et al., 2010), a key variable with regards to health, social service interventions and evidence-based clinical practices. Deepening our understanding of potential moderators of cognitive aging such as QoL is crucial to promoting well-being in the growing older adult population.

The overarching aim of this study was to investigate the moderating role of QoL over age-related EFs differences. A seminal taxonomy of EFs (Miyake et. al, 2000, 2012) and the work of the World Health Organization (WHO) on QoL (Power et al., 2005) inspired this endeavor. Six tasks of EFs related to Shifting, Updating, and Inhibiting and self-reported QoL based on the WHOQOL-BREF and -OLD were utilized with 102 community-dwelling, healthy older adults (M = 73.11 years; age range: 60 - 94). A moderation analysis was used to assess if QoL (moderator) buffers the relationship between age (IV) and EFs indicators (DV). Regression and MANCOVA analyses were conducted to evaluate age-related differences in EFs and the following prominent theories: *the processing speed theory* (Salthouse, 1996), *inhibition deficit* *theory of cognitive aging* (Hasher & Zacks, 1988), and *dedifferentiation hypothesis* (Garrett, 1946).

As predicted, age significantly contributed to task performance for most EFs indicators, above and beyond processing speed. As expected, statistically significant moderation interactions were found for several executive indicators and QoL domains, illustrating the buffering role of QoL over age-related differences in EFs. Specifically, QoL items related to the environment, sensory abilities, and social engagement domains, and EFs indicators related to Inhibiting, showed the most notable moderating effects. Implications for these results and the role of covariates were discussed. An emphasis was placed throughout on the importance of investigating QoL variables and other moderating factors of cognitive aging, for the development of prevention and intervention endeavors with older adults.

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Acknowledgments

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Dedication

This dissertation is dedicated to my Victoria-family, my far-away friends, my parents, and most of all, to my partner Peter. Your kindness, generosity and support were central to my success in graduate school, including but not limited to this project. I thank you all sincerely.

Introduction

Several definitions and models of Executive Functions (EFs), a specific subset of cognitive abilities, exist. A recent definition proposed by Diamond (2013) appears to encapsulate some of the most fundamental characteristics of these functions: “a family of top-down mental processes needed when you have to concentrate and pay attention, when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible.” (p.136). Despite the notable heterogeneity that exists in descriptions of this construct (see Jurado & Rosselli, 2007 for a review), one aspect of EFs seems to have gained unanimity in the field; that is, the deliberate nature of EFs (Diamond, 2013). It has become increasingly obvious that the term EFs describes those functions necessary in the face of novel tasks, consequently requiring intentional action (Dores et al., 2014). This principle will be explored throughout this dissertation. While our understanding regarding the purpose of these abilities keeps improving, how they are structured and organized is still widely debated. Indeed, numerous theoretical and conceptual frameworks of EFs appear to conflict with one another. A three-factor statistical model was put forth by Miyake and colleagues (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) and has gained significant attention since its publication. It will be made evident in this dissertation that this model serves as an inspiration for the current investigation.

Another area that is important to this discussion and prominent in the field of EFs is the lifespan neurodevelopmental trajectory of growth and decline pertaining to EFs. In fact, much of our understanding of changes affecting EFs and differences throughout life comes from research looking at the neural mechanisms underlying these abilities. Early development and later aging-related changes affecting the brain are said to be anatomically very similar (Tamnes et al., 2013). Specifically, lifespan changes impacting the prefrontal cortex (PFC) appear to be closely linked with both earlier functional gains as well as later losses affecting cognitive abilities (e.g., Diamond, 2013). In line with this, the PFC is said to be one of the last areas to fully mature and to be the most vulnerable to aging changes (Fuster, 2015). Although optimal EFs require whole-brain integrity involving efficient communication between anterior and posterior cortices (Fisk & Sharp, 2004; Zelazo & Muller, 2002), there is agreement that one area, the PFC, acts as the seat of EFs (e.g., Banich et al., 2000; Bechara, Damasio, Damasio, & Anderson, 1994; Fuster & Bressler, 2015; Grady, 2008, 2012; Jurado & Rosselli, 2007; Kesner & Churchwell, 2011). In fact, the construct of EFs arose from studies targeting brain injury patients who had apparent damage to the PFC (Shallice & Burgess, 1991). These patients showed concomitant deficits in mental and behavioral skills, such as planning and goal-oriented behaviors, which are now essentially thought of as executive.

Given the PFC's recognized and central role in supporting EFs, its association with different developmental periods has been thoroughly investigated (see Craik & Bialystok, 2006; Zelazo, Carlson, & Kesek, 2008). In line with this, performance discrepancies on tasks tapping onto EFs have been found across the lifespan (e.g., shifting and working memory in younger and older children/adolescents, Huizinga, Dolan, & van der Molen, 2006; shifting in middle-aged and older adults, Hull, Martin, Beier, Lane, & Hamilton, 2008). The development and decline of these functions has been depicted as an inverted U-shaped trajectory across the lifespan (Zelazo, Craik, & Booth, 2004) associated with performance improvement on EFs tasks until young adulthood, and, conversely, with declines in these abilities during the sixth decade of life (Schaie, 2013). It should be noted that the term decline is associated with various interpretations and implications. To clarify, it will be used to represent changes affecting EFs in an unfavorable, yet not necessarily functionally deleterious manner, for the rest of this dissertation.

Another important clarification must be made with regards to the term 'older adult'. It is generally understood that older adulthood begins during the sixth decade of life. The age of 60 is the agreed-upon cutoff set by the United Nations to refer to the older population (see WHO, 2010). The World Health Organization's (WHO) defines the chronological age of 65 years as a definition of 'elderly' within the context of most developed countries (i.e., generally equivalent to age of retirement).

Moreover, as it will be argued later, there exists notable disagreement and uncertainty regarding the specific nature of change affecting EFs in the last decades of life (see reviews by Banich, 2009 & Jurado & Rosselli, 2007). Separate and/or convergent trajectories of specific EFs associated with healthy aging are still under study (Crevier-Quintin, 2013). Nevertheless, they are generally said to be the "first out," compared to other cognitive functions, as we get older (Craik & Bialystok, 2006; Luszcz, 2011). This age-effect seems to impact our ability to manage internal and external demands, thereby affecting independence and productivity in older adulthood (Lezak, Howieson, & Loring, 2004).

Perhaps not surprisingly, the physiological and structural changes associated with aging and EFs are thought to have consequences on most aspects of everyday life (Diamond, 2013, 2014). Increased risk for falls (Mirelman et al., 2012), social inappropriateness (Henry, von Hippel, & Baynes, 2009), loneliness (Quintin, Cochrane, & Garcia-Barrera, 2015; Tun, Miller-Martinez, Lachman, & Seeman, 2013), reduced perspective taking (Bailey & Henry, 2008), and Instrumental Activities of Daily Living (IADLs; e.g., managing finances and remembering appointments; Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010) for instance, seem to be correlated with these changes. Of particular interest for the current study is the relation between these late-life fluctuations over subjectively and objectively appraised life satisfaction, also known as Quality of Life (QoL). Specifically, given the multidimensional repercussions of age-related EFs decline, it seems reasonable to assume that the QoL of older individuals would subsequently and indirectly be altered. This seems of importance given today's growing aging population and the need for evidence linking factors and resources contributing to the maintenance and growth of QoL in older adults. This will be examined further later.

In line with what has been discussed so far, the first aim of this dissertation will be to describe research pertaining to aging and EFs, such as important theories of later life maturation. The second target will be to describe notable findings pertaining to QoL and specifically related to the older adult population. Finally, the present study will strive to address what is known regarding lifestyle variables and factors related to QoL in older adults, and what is unknown regarding their particular correlation with vulnerable EFs in old age. More specifically, the overarching goal of this discussion will be to outline an important gap in the literature pertaining to the potential moderating role of QoL over the well-documented relationships between aging and EFs fluctuations.

Review of Pertinent Literature

Executive Functions

Definition. Decades ago, the work of Soviet neuropsychologist A. R. Luria provided a groundbreaking conceptualization of the brain's cortical units (e.g., Luria, 1973). Interestingly, his depiction of the frontal lobes' functions, emphasizing their higher-order role, resembles current interpretations of EFs. Luria suggested, for instance, that the primary frontal zone monitors "the effect of the action carried out and verification that it has taken the proper course" (1973, p. 93). He also recognized the importance of whole brain involvement; that is, the need for assimilating hierarchically-organized subsystems to successfully produce EFs (Fisk & Sharp, 2004; Zelazo & Muller, 2002). Undoubtedly, Luria's unprecedented studies continue to inspire research on EFs and the frontal lobes today.

Currently, definitions of EFs not only generally acknowledge their supervisory properties, as suggested by Luria, but also emphasize their critical role when faced with change and novelty. As mentioned earlier, EFs are thought to be crucial to the generation of complex thoughts and actions, above and beyond the restrictions of our 'default' abilities (e.g., Marien, Custers, Hassin, & Aarts, 2012; Zelazo, & Carlson, 2012). Despite their recognized influence over non routine-like tasks (Banich, 2009), determining which functions should be specifically labeled as executive continues to represent a topic of debate. Executive functioning undoubtedly remains an elusive construct (Jurado & Rosselli, 2007). On one side, for instance, some have suggested that EFs represent a global construct akin to the general factor of intelligence, *g*, whereas others have argued that it is a multicomponent construct, as will be discussed next (see Friedman et al., 2008). The following section will focus on a taxonomy that has gained popularity and momentum over the last 15 years, since its original dissemination, as well as age-related effects associated with this model.

Taxonomy. Miyake et al. (2000) proposed a pivotal three-factor statistical model of EFs. One of their aims was to provide “a necessary empirical basis for developing a theory that specifies how EFs are organized and what roles they play in complex cognition" (p.50), without explicitly putting forth a model of EFs per se. Since then, their influential taxonomy has been studied extensively and used as an empirical prototype in the study of EFs (see for e.g., Adrover-Roig, Sesé, Barceló, & Palmer, 2012; Crevier-Quintin, 2013; de Frias & Dixon, 2014; Fisk & Sharp, 2004; Hofmann, Schmeichel, & Baddeley, 2012; Hull et al., 2008; Karr, Garcia-Barrera, & Areshenkoff, 2014; Pettigrew & Martin, 2014; Sorel & Pennequin, 2008). Miyake and colleagues’ study targeted individual differences in EFs among college students specifically related to task performance for mental set shifting (‘‘Shifting’’), information updating and monitoring (‘‘Updating’’), and inhibition of prepotent responses (‘‘Inhibiting’’), three components that were said to dominate the literature at that time (e.g., Baddeley, 1996; Logan, 1985; Lyon & Krasnegor, 1996; Rabbitt, 1997). Of note, another important factor weighing into the selection of these three constructs was that they represent “relatively circumscribed, lower level functions (in comparison to some other often postulated executive functions like ‘‘planning’’)” (Miyake et. al, 2000, p.55). The authors assessed the contribution of each function to a set of well-known “complex” executive tasks (i.e., the Wisconsin Card Sorting Test, Tower of Hanoi, random number generation, operation span, and dual tasking), each thought to tap at least one of the target functions. What was innovative about their work and what perhaps resulted in such recognition, is that Miyake and colleagues argued for both the global and specific aspects of EFs, largely divided camps at that time. More specifically, they reconciled the ideas of unity and diversity, originally proposed by Teuber (1972). They suggested that EFs can be divided into separate complex subcomponents, thus possessing discriminant validity, while also corroborating their convergent validity. Accordingly, their latent variable and confirmatory factor analyses suggested that the subcomponents were best represented by a three-factor model with clearly correlated yet distinct components, which uniquely contributed to performance on the complex executive tasks mentioned above. Their "unity/diversity framework" (Miyake & Friedman, 2012) provided empirical support for a system of higher-order functions which (a) contribute differentially to performance on relevant tasks, and (b) require a certain level of interaction to create the desired output. Also, it is likely that the latent-variable approach used in this study accounts for some of the attention it received; namely, this statistical method deals with an issue inherent to measuring multifaceted functions such as EFs' task-impurity (Burgess, 1997). Miyake and colleagues were able to obtain "purer" variables by statistically extracting common variance across tasks, which led to their conclusions regarding three separable and connected latent variables.

Aging and the three-factor framework. Although the central executive is generally thought to be divisible into at least three discrete component processes (Adrover-Roig et al., 2012), aging-trajectories for each of these EFs are not yet well understood. It is widely recognized, however, that age-related changes affecting functions subserved by the PFC and interrelated networks, are quite complex. As it will be described later, some have argued, for instance, that not all EFs decline at the same rate (see for e.g., *the inhibition deficit theory of cognitive aging* by Hasher, Lustig, & Zacks, 2007; Hasher, Stolzfus, Zacks, & Rypma, 1991); that is, certain facets of the executive system are thought to change more notably than others as we get older. A previous study comparing younger (ages 30-40), middle-aged (50-60), and older adults (70 and older) on five EFs tasks only revealed statistically significant differences between middle-aged and older adults on two tasks (i.e., tasks of updating working memory and inhibitory control), favoring participants aged 50-60 (Crevier-Quintin, 2013). These results suggested the relative stability of certain functions (i.e., shifting, reward and valence processing, and problem representation) from younger to older adulthood. Additionally, there was no main effect for EFs as a function of age. All in all, these results suggest a heterogeneous process of change across the adult lifespan. A focused review of findings pertaining to the specific vulnerability of updating, shifting and inhibition is presented, followed by discussion of age-related changes and relevant theories.

EF components. *Updating* refers to the ability to efficiently monitor the content of Working Memory (WM) and to add or delete information (i.e., update) accordingly (e.g., Adrover-Roig et al., 2012; Crevier-Quintin, 2013; Fisk & Sharp, 2004; Friedman & Miyake, 2004; Miyake et al., 2000). *Shifting* refers to the ability to efficiently alternate between tasks or mental sets thereby controlling where attention is allocated. And, *Inhibiting* refers to the ability to efficiently and deliberately ignore or suppress prepotent responses. As noted earlier, the deliberate aspect of each of the components is essentially what renders them as executive.

The definitions above evoke the interconnectedness of the components and the executive system overall. As suggested by Diamond (2013), for instance, we are hard-pressed to think of instances when Inhibiting is required in the absence of Updating WM, and vice-versa. Inhibiting is required to prevent irrelevant information from entering Updating WM. In turn, Updating is needed to hold in mind the information that must be suppressed by inhibitory skills and to refresh cognitive content accordingly. It has been purported that these functions depend on the same capacity-limited systems; namely, system failures for both Inhibiting and Updating may occur when either one of these functions is overloaded (e.g., Engle & Kane 2004; Wais & Gazzaley 2011). Updating and Shifting are also said to share activation networks involving the PFC and parietal cortices (Diamond, 2013). Specifically, an exploration of the neural substrates associated with these three EFs demonstrated that common foci of activation include the right intraparietal sulcus, the left superior parietal gyrus, and the left lateral prefrontal cortex (Collette et al., 2005). In keeping with this, it seems reasonable that relatively intact Shifting capacities would be needed to efficiently and appropriately renew the content of WM, by, for example, shifting one's attention to relevant information (e.g., Gazzaley & Nobre 2012; Ikkai & Curtis 2011; Nobre & Stokes 2011). In turn, directing one's attention towards pertinent stimuli inherently involves the capacity to turn away from and delete irrelevant stimuli (i.e., Inhibiting).

Given their interconnected roles and the involvement of overlapping neural activation, interactions among these three EFs and across the adult lifespan is expected to be multifaceted. This seems to be supported empirically, as cited herein.

Age-related changes. In line with the relations described above, aging declines are thought to have mutual and cascading effects on the three components. Age-related declines in Updating, for instance, are thought to largely result from age-related changes in Inhibiting (Hedden & Park 2001; Solesio-Jofre et al. 2012). In fact, it has been suggested that declining inhibitory skills results in greater vulnerability to proactive and retroactive interference, which thereby affects Updating (Rutman, Clapp, Chadick, & Gazzaley, 2010; Zanto & Gazzaley 2009). The age-related decline affecting the ability to suppress extraneous information would thus be partially responsible for decreased monitoring of WM content.

Described in the next section, some have suggested that declines of inhibitory capacity explain more than just reduced Updating skills in old age. Moreover, Inhibiting declines are often said to account for most cognitive changes associated with normal aging (Hasher et al., 2007; Hasher, et al., 1991; Hasher & Zacks, 1988; Hasher, Zacks, & May, 1999). Various types of inhibitory skills are thought to change with old age. For instance, reduced Inhibiting for distractions, both visual (Darowski, Helder, Zacks, Hasher, & Hambrick 2008; Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005) and auditory (Alain & Woods 1999; Barr & Giambra 1990) has been documented, even when warning regarding incoming irrelevant information is presented (Zanto, Hennigan, Ostberg, Clapp, & Gazzaley, 2010). Overall, the greater sensitivity to interference associated with older age is thought to underlie cognitive differences between younger and older adults, which subsequently impacts both Inhibiting and Updating.

Finally, aging trends like those described so far have also been found for Shifting. Normal aging is thought to be associated with an increased tendency to focus attention on salient environmental stimuli (Karayanidis, Whitson, Heathcote, & Michie, 2011; Munakata et al. 2011; Munakata, Snyder, & Chatham, 2012), which may disrupt the level of efficiency and flexibility in attentional control. This would appear to be comparable to what is known about early cognitive developmental phases. The ability to deliberately direct one's attention to relevant stimuli, involving some level of planning and anticipation, has been found to be better in older children and young adults, than in young children and older adults (Diamond, 2013). In fact, young children and older adults are said to generally use EFs in a more reactive rather than proactive manner, which would subsequently impact Shifting. More precisely, cognition in childhood and older adulthood is associated with fewer planning and anticipatory strategies compared to other stages of life (e.g., Karayanidis et al., 2011; Munakata et al., 2012). In keeping with this, it is likely that older adults use Shifting skills in a less deliberate manner than their younger counterparts, due to age-related processes affecting EFs. Given the known relationships among EFs components, one would also expect vulnerability to interference affecting Updating and Inhibiting to contribute to differences in Shifting abilities across the adult lifespan. More specifically, distractions disturbing Updating and Inhibiting could possibly diminish Shifting capacities.

Overall, the ways in which age-related changes impact Shifting, Updating, and Inhibiting seem to be intertwined. Consequently, distinguishing their unique influence over performance on cognitive tasks is challenging. It is crucial that future studies continue fostering our understanding of the specific role of these EFs with regards to aging. The growing literature on empirical theories of cognitive aging over the last twenty years has contributed to this and has further reinforced the complexity of unfolding EFs during the golden years. In keeping with the discussion on age-related cognitive trajectories pertaining to EFs, some of the most prominent and relevant theories will be explored next, as these theoretical frameworks help shape our knowledge of the sensitivity and resilience of particular elements of the executive system.

While it is somewhat beyond the scope of this dissertation, a distinction between different age-related EFs changes should be noted here; that is, the detrimental effects of old age have been argued to be limited to traditional EFs such as those described herein. According to the Socioemotional Selectivity Theory (Samanez-Larkin, Robertson, Mikels, Carstensen, & Gotlib, 2014), older adults' susceptibility to cognitive interference is specific to non-emotional EFs (i.e., EFs that do not tap onto emotional concepts or stimuli). More specifically, this theory suggests that the ability to regulate emotions generally remains stable or actually improves throughout adulthood. Correspondingly, the response of older adults to EFs tasks that are emotionally salient is said to be similar to younger adults (i.e., no significant difference in their performance on emotional EFs tasks). All in all, the detrimental effect of old age over performance on traditional EFs tasks does not seem to be supported for EFs tasks drawing onto emotional resources.

Theories of Age-Related Changes in EFs

Using various theories, several studies looking at aging and EFs have attempted to explain both global and specific changes occurring at this developmental stage. Some of the more prominent ones include *the processing speed theory* (Salthouse, 1996), *the prefrontal-executive theory* (West, 1996), *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988; Darowski et al., 2008; Hasher et. al, 2007), and *the dedifferentiation hypothesis* (Garrett, 1946). These theories have undoubtedly impacted the field of EFs research and, correspondingly, have shaped the current study. The next sections will take a closer look at these four influential propositions and will examine evidence related to each of them.

Processing speed theory (Salthouse, 1996). This theory stipulates that cognitive aging results from one global mechanism: slowed processing speed. According to this theory, higher-order abilities are said to decrease in older age due to a general slowing of the underlying functions necessary to execute these more complex skills. White matter integrity is said to be particularly vulnerable to aging-related changes in the brain, which, grossly put, subsequently impacts the efficiency and speed at which different parts of the brain communicate with each other (Gunning-Dixon & Raz, 2000). In other words, areas subserving the foundational skills needed to create EFs would be said to interact at an increasingly slower pace after a certain age. This, in itself, would result in the repeatedly documented outcome of age-related declines in EFs.

In support for this theory, studies controlling for processing speed in contrast to other cognitive domains have showed reduced or non-significant performance differences across adulthood (e.g., Bryan & Luszcz, 1996; Finkel, Reynolds, McArdle, & Pedersen, 2007; Hertzog & Bleckley, 2001). Similarly, processing speed was found by some to be a mediator of declining EFs with age (Adrover-Roig et al., 2012; Rabbitt et al., 2007). Numerous neuroimaging studies have also suggested that age-related white matter disruptions are indicative of generalized slowing in the brain and account for decreased cognitive performance in older adults (e.g., Gunning-Dixon, Brickman, Cheng, & Alexopoulos, 2009; Gunning-Dixon & Raz, 2000; Madden, Bennett, & Song, 2009).

Prefrontal-executive theory (West, 1996). This theory suggests that the well-known age-related vulnerability of the anterior lobes, the "seat" of EFs, is responsible for causing a decline in executive skills in older adulthood. Numerous studies have provided evidence for this, suggesting age-related changes in the PFC above and beyond other cortical areas (e.g., Fisk and Sharp, 2004; Jurado and Rosselli, 2007; Phillips & Henry, 2008).

Although appealing, the idea that the PFC is the primary and perhaps sole cerebral structure accountable for cognitive aging has been widely criticized (Braver et al. 2001; Greenwood 2000; Rubin 1999). It is now better understood that involvement of the entire brain is most likely required for intact EFs (Fisk & Sharp, 2004; Zelazo & Muller, 2002). Nevertheless, the crucial role of the PFC with regards to EFs and its vulnerability to aging processes seems to be uncontested and is worth mentioning here.

Overcoming challenges with Salthouse and West's theories. As will be addressed next, it is likely that the unidimensional quality of the two theories above diminishes their validity. Solely targeting a single functional (Salthouse, 1996) or neuroanatomical (West, 1996) mechanism seems too parsimonious to explain complex cognitive aging processes. Beyond their single-focus, another factor seems to complicate our evaluation and appreciation of these theories. Namely, there seems to exist comparable amounts of evidence corroborating each of them.

All in all, it is likely that both target processes co-occur to some extent with old age and account for separate aspects of age-related cognitive losses. An integrative theory which considers both the functional and neuroanatomical changes associated with older age would be ideal. Interestingly, few seem to have utilized such an approach. Schretlen and colleagues (2000) found that speed, executive ability, and frontal lobe volume each made significant contributions to a regression equation explaining the majority of the variance in fluid intelligence in participants between the ages of 20 and 92. This suggests that these components all contribute to some aspect of cognitive aging and should ideally be investigated concurrently rather than separately. Evidently, the resources necessary to evaluating both functional and neuroanatomical changes are not available to all. Financial resources and access to related measures only represent part of the challenge. Various additional limitations exist, affecting the possibility for, and/or interpretation of such research, such as the heterogeneity in tasks typically used to evaluate the validity of these theories, the dearth of comparative groups or norms, and the absence of discussions focusing on the commonalities shared by processing speed and EFs (Albinet et al., 2012). Based on these limitations, a theory-based methodological framework with more carefully selected and empirically-supported tasks, and a clear theory-based rationale for task selection, is greatly needed.

Furthermore, Albinet and colleagues (2012) proposed a theory-based methodological framework. They investigated performance difference in younger (18-32 years) and older (65-80) healthy adults on nine commonly used tasks for Shifting, Updating, and Inhibiting, and included experimental and psychometric tests of processing speed. Their hierarchical regression analyses revealed that EFs and processing speed shared mutual variance while being independently affected by aging. Also, they found that increasing age uniquely affected both constructs of processing speed and EFs, while showing a greater effect for processing speed than EFs. They concluded that their study corroborates both *the processing speed* and *the prefrontal-executive* theories and emphasized their mutual relationship and effect over higher-order skills in old age.

Inhibition deficit theory. Originally proposed by Hasher and Zacks (1988; see also Bell, Buchner, & Mund, 2008; Darowski et al., 2008; Hasher et al., 1991; Hasher et al., 1999; Hasher et al., 2007), this theory resembles *the processing speed theory* in terms of its specificity; that is, Hasher and Zacks emphasized the crucial and unique role of inhibitory control over other EFs and its accountability over age-related cognitive decline. The authors focused on inhibition to explain detrimental changes in memory processes with increasing age. They proposed that age-related cognitive costs associated with memory are due to declines in the ability to inhibit information in WM (akin to the concept of Updating). They suggested that this effect has multifaceted impacts on cognitive functioning since WM is crucial to performance across various domains (see Baddeley & Hitch, 1994 for a seminal description of this construct). In other words, Hasher and Zacks claimed that cognitive changes in older adulthood are due to the indirect effects of loss of WM integrity (or Updating), which is directly impacted by diminished inhibitory skills. Reduced inhibition with increased age is therefore said to have repercussions on performance decrements exhibited on a variety of cognitive tasks. Of note, much like current depictions of EFs, these authors described the importance of efficient inhibitory skills over goal-directed actions. They highlighted how age-related compromised inhibition allows irrelevant information to enter WM, which in turn can prevent older adults to focus on goal-pertinent information. Thus, “a person with reduced inhibitory functioning can be expected to show more distractibility, to make more inappropriate responses and/or to take longer to make competing appropriate responses, and, finally, to be more forgetful than others” (Hasher and Zacks, 1988, p. 215). Analogous to *the processing speed theory*, Hasher and Zacks’ interpretation of the role of inhibition in adulthood puts forth a valuable but possibly constrained explanation of related cognitive changes (see Burke, 1997 for a critical review). Again, a more integrative approach would likely enhance the strength of this proposition.

Regardless of this potential limitation, many have also claimed that inhibition is a crucial contributor and/or the primary determinant of age-related cognitive deficits (e.g., Bell et al., 2008; Charlot & Feyereisen, 2004; Crevier-Quintin, 2013; Dempster, 1992; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Persad, Abeles, Zacks, & Denburg, 2002; Pettigrew & Martin, 2014; Rodríguez-Villagra, Göthe, Oberauer, & Kliegl, 2013; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein 1993). Of interest here, using Confirmatory Factor Analysis looking at Miyake’s components, a distinct factor for inhibition (i.e., representing a distinct EF) was found to disappear with old age (Hull et al., 2008). This result may be interpreted in several ways. One interpretation may be that it underlines the sensitivity of the cognitive system to inhibitory declines, as suggested by *the inhibition deficit theory of cognitive aging*. Comparably, recent neuroimaging studies targeting areas crucial to inhibition such as the Dorsolateral Prefrontal Cortex, found it to be one of the strongest predictors of aging declines (e.g., Adólfsdóttir et al., 2014; MacPherson, Phillips, & Della Sala, 2002).

Dedifferentiation hypothesis. Finally, the last seminal theory that will be addressed here is *the dedifferentiation hypothesis* (Balinsky, 1941; Garrett, 1946; Anstey, Hofer, & Luszcz, 2003). This hypothesis was founded in developmental theories looking at intelligence and trajectories of cognitive function across the lifespan. It originated from *the age differentiation hypothesis*. As the name suggests, this theory supports the view that the structure of intelligence is unified earlier on in development (i.e., *g* factor) and gradually becomes fragmented into a set of discrete abilities as youths mature (Garrett, 1946). *The dedifferentiation hypothesis* predicts the reverse process, that is, the de-fragmentation of distinct functions in older adulthood. According to these hypotheses and expanding upon the theoretical ideas of unity and diversity (Teuber, 1972), earlier (childhood) and later (older adulthood) stages of life are hypothetically marked by more cognitive unity, and the remainder of life, by cognitive diversity.

An adequate and empirical evaluation of *the dedifferentiation hypothesis* is imperative, and longitudinal models represent an ideal approach for assessing these types of aging theories. Data from a 2007 study (de Frias, Lövdén, Lindenberger, & Nilsson) looking at 1000 non-demented adults between the ages of 35 and 80, for example, provided support for this hypothesis. Age-related increases in correlations among performance scores across various cognitive measures were observed later (ages 65 and over) but not earlier in adulthood. The authors concluded that these results suggest dynamic dedifferentiation with old age (progressive increased correlations amongst cognitive functions). This thereby also suggests a shift from cognitive diversity to unity from early to late adulthood.

Notwithstanding these findings, longitudinal methods have also provided data discrediting the target hypothesis. For instance, a longitudinal study (Batterham, Christensen, & Mackinnon, 2011) looking at 896 Australian adults aged 70 and over for up to 17 years, was unable to corroborate *the dedifferentiation hypothesis* in healthy older adults. Although age dedifferentiation effects were observed in some participants, they were attributed to mortality-related pathology. In fact, surveying the literature reveals numerous studies using similar and different methodology that also contradict the hypothesis. Combined longitudinal and cross-sectional data arising from another Australian longitudinal study over an eight-year period (Anstey et al., 2003), for example, looking at age group differences, ability group differences, attrition group differences, and time, revealed dedifferentiation but not with regards to age. Specifically, the sample of 1,823 adults of ages 70+ only revealed inconsistent dedifferentiation effects associated with low ability and early attrition from the study. Likewise, using a simple cross-sectional design to evaluate the target hypothesis, looking at 1,369 subjects between the ages of 16 and 94, Juan-Espinosa and colleagues (2002) found no changes in the amount of variance explained by *g* and four group factors related to intelligence. In a relatively recent cross-sectional investigation, Tucker-Drob and Salthouse (2008) also provided comparable evidence supporting continued differentiation with age, in 2,227 adults between the ages of 24-91.

Navigating the literature regarding models of aging changes associated with EFs proves once again to be challenging. While earlier studies seemed to corroborate *the dedifferentiation hypothesis* (e.g., Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980; Cornelius, Willis, Nesselroade, & Baltes, 1983; Green & Berkowitz, 1964), nowadays, equivalent evidence appears to be quite scarce.

Reconciling theories of EFs. The reorganization of EFs across adulthood is a topic that has gained exponential attention in the last decades but that has yet to reach consensus. Many theories and hypotheses have attempted to describe the specific changes affecting higher-order skills in older adults. The ones described above represent some of the most influential ones but it should be noted that numerous others exist. As none of these propositions has provided sufficient evidence to explain the nature of change for these processes, it is suggested herein that a more integrative approach be used in future research, including the present. In line with this, as it will be outlined later, the current dissertation proposes a cohesive perspective of the theories above as a novel approach to evaluating the aging of EFs. More specifically, as suggested by Albinet and colleagues (2012), we propose that using a theoretically and methodologically-driven framework to assess complex aging processes associated with EFs is crucial. Investigating the relationships among well-known measures and the prominent theories described here seems relevant at this juncture.

In line with this, this study will consider *the processing speed theory* (Salthouse, 1996), *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988), and *the dedifferentiation hypothesis* (Garrett, 1946) from a methodological point of view. Due to limitations around resources allocated to this study (i.e., no access to neuroimaging technology), *the prefrontal-executive theory* (West, 1996) will only be acknowledged from a theoretical standpoint, as suggested by others (e.g., Albinet et al., 2012) and acknowledged as part of the rationale which makes EFs the target cognitive focus of this study (versus other cognitive functions).

Potential Implications of Changes in EFs in Later Life

EFs and everyday life. As shown above, the vulnerability of EFs to normal aging appears undisputed; although, the specific manner in which this unfolds is highly questionable. Nevertheless, given their widely known contribution to most aspects of everyday life (Diamond, 2013), changes at this level would be expected to result in revision, adaptation, and modification in lifestyle. An empirically-established construct that represents multifaceted daily life activities that are associated with cognitive functioning and independence in older adults is Instrumental Activities of Daily Living (IADLs; e.g., McGuire, Ford, & Ajani, 2006). Notably, EFs have been suggested to predict IADLs in older adults better than global cognition does (Bell-McGinty, Podell, Franzen, Baird, & Williams, 2002; Jefferson, Paul, Ozonoff, & Cohen, 2006; Royall, Palmer, Chiodo, & Polk, 2004). The correlation between EFs and functional status has even been demonstrated in older adults (60-90) using Miyake's three-factor model (Vaughan & Giovanello, 2010). The studies cited herein only represent a minute portion of empirical investigations in this subfield, yet they point to an important fact; that is, the seemingly significant influence EFs have over performing everyday activities and the potential role they play in the conservation of independence and related skills in older adults.

In turn, an extension of this effect is the impact of compromised EFs on ratings of lifestyle satisfaction and value; that is, a change in the ability to perform daily activities could reasonably be presumed to affect subjective perceptions or objective underlying factors pertaining to one's circumstances. In other words, as EFs and IADLs concurrently change and potentially decline with age, presumably so would individual appraisals regarding the quality of conditions under which older adults live. A construct that captures such appraisals and which will be reviewed more extensively shortly, is Quality of Life (QoL). A key point is the apparent existence of relationships between QoL, cognition and functional status. More specifically, cognitive aging has been found to be associated with lowered QoL and decreased functional independence (Gaugler, Duval, Anderson, & Kane, 2007; Tabbarah, Crimmins, & Seeman, 2002). In home-dwelling elders, for instance, physical and cognitive function deficits have been found to be among primary predictors of decreased QoL (Borowiak & Kostka, 2004). Of note, the role of self-efficacy has been suggested to be responsible for the relationship between physical activity and QoL, which aligns with previous findings related to functional independence (White, Wójcicki, & McAuley, 2009). Similar to IADLs, QoL has been said to vary based on the integrity of the executive system in various populations including healthy older women (Davis et al., 2010), adults with schizophrenia (Tyson, Laws, Flowers, Mortimer, & Schulz, 2008), Attention Deficit Hyperactive Disorder (Brown & Landgraf, 2010), Parkinson's Disease (Kudlicka, Clare, & Hindle, 2014), epilepsy (Wang & Zhou, 2014), and cerebral small vessel disease (Brookes et al., 2014). Overall, various conditions associated with altered EFs are thought to contribute to impairments in numerous domains of major life activities underlying QoL ratings. It should be noted here that the majority of studies targeting EFs and QoL involve populations known to have concomitant cognitive concerns. Also, the direction of this relationship is unclear and causality has yet to be established. In any case, based on the findings outlined here, interactions between changes in EFs and QoL in healthy older adults seem highly plausible. Given what we know regarding EFs and aging, and EFs and IADLs, it is conceivable that components underlying QoL, including but not limited to IADLs, would act as moderators for the degree of age-related decline in EFs. In the same vein, higher levels of QoL ratings could potentially act as a buffer for the extent to which EFs suffer with old age, whereas lower QoL may exacerbate EFs-related declines. Surprisingly, research supporting this association appears to be scarce.

Of note, in this context, a moderator (e.g., QoL) represents a variable that alters the strength of the relationship between two other variables (the dependent and independent variables; e.g., EFs and aging). A linear causal relationship in which the independent variable (e.g., aging) is thought to cause the dependent variable (e.g., EFs) is the foundation of the moderation interaction (Baron & Kenny, 1986). Also, moderation is not to be confused with mediation, in which case a mediating variable explains or accounts for the relationship (instead of simply enhancing or diminishing it) between the independent and dependent variables.

As it will be shown later, surveying the literature for this particular relationship is puzzling. Statistically significant correlations between lifestyle variables (not explicitly conceptualized as QoL) and global cognition (not explicitly labeled as EFs) in older adults do exist, however. Namely, evidence for the association between higher levels of social engagement, often used as an indicator of QoL, and reduced cognitive declines in older adults, is abundant (e.g., Barnes, de Leon, Wilson, Bienias, & Evans, 2004; Bassuk, Glass, & Berkman, 1999; Ertel, Glymour, & Berkman, 2008; Fratiglioni, Paillard-Borg, & Winblad, 2004; Lövdén, Ghisletta, & Lindenberger, 2005; James, Wilson, Barnes, & Bennett, 2011; Seeman, Miller-Martinez, Stein Merkin, Lachman, Tun, & Karlamangla, 2011). This finding points to the potential moderating role of at least one QoL component over cognition in old age. What seems uncertain however, is if this is also true for other indicators of QoL, and if this effect impacts the skills most vulnerable to aging processes (i.e., EFs). As such, the current study will aim to address a gap in the current literature, pertaining to the potentially important connection between QoL and EFs in old age. First, a review of the relevant QoL literature, including definition and pertinent constructs, is necessary.

Quality of Life

Some have argued that origins of discussions around QoL date back to Aristotle and his concept of 'the good life' (Netuveli & Blane, 2008). "Aristotle held that a particular variety of happiness was the greatest good, a happiness dealing not merely with pleasure but with the combination of pleasure and virtue." (Bauer, McAdams, & Sakaeda, 2005, p.203). Even if this philosophical description is too simplistic to capture modern views on QoL, it outlines the longstanding societal value that has been placed on this construct.

Definition. Remarkably, since Aristotle, QoL has been defined and conceptualized in a myriad of ways. As wittily outlined by Hambleton, Keeling and McKenzie (2009) in a review of QoL literature specifically related to older adult populations, "[t]he literature on [QoL] can be described as a jungle: vast, dense and difficult to penetrate, especially for those entering the field without a specialist [QoL] background." (p.3). Yet, one definition put forth by the WHO, a pioneer in the field of QoL measurement, is widely utilized and seems closer to reaching consensus compared to any other definition. The WHO defines QoL as ''individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards, and concerns.'' (1993, p.1). This definition effectively emphasizes the subjectivity and individuality of the meaning and appraisal of QoL. These aspects are particularly relevant to the current study, given the target population (i.e., older adults) and the need to specifically consider QoL in an age-appropriate manner.

Taxonomy. The WHO has researched QoL extensively and has created assessment measures tapping broad and relevant domains such as physical and mental health, social functioning, and emotional well-being (Baernholdt, Hinton, Yan, Rose, & Mattos, 2012). Each of these general domains can be broken down into more specific variables or so called objective and subjective indicators (Hambleton et al., 2009). Objective indicators represent empirically-derived and quantifiable entities, while subjective indicators are based on the premise that each individual is the best judge and assessor of their own life's worth. With the use of factor analysis, subjective and objective QoL components have been found to represent separate latent variables (e.g., subjective satisfaction, objective work/income/leisure and objective living situation/safety; Ruggeri, Bisoffi, Fontecedro, & Warner, 2001), thus indicating distinct aspects of QoL. Examples of objective indicators are, including but not limited to, rates of home ownership, employment, income, marital status, hospitalization and mortality. Examples of subjective indicators are, including but not limited to, feelings, attitudes, preferences, judgments, life and job satisfaction, and happiness. Although there seems to be some agreement regarding the validity of some indicators of QoL, specific items and associated measures tapping onto this construct have yet to reach consensus (e.g., Halvorsrud & Kalfoss, 2007). It appears QoL assessment tools differ largely based on the discipline (e.g., psychological, sociological, and political sciences; see for e.g., Baernholdt, et al., 2012). QoL is indeed a concept that is relevant to various fields due to its implications in healthcare, politics, the military, business, and finances. The manner in which it is conceptualized and measured varies accordingly. The most widely used measures of QoL typically fall into the broad (vs. domain-specific) category as they conceptualize QoL as an umbrella term under which physical, mental, and social aspects of an individual's life fall (Baernholdt, et al., 2012).

In keeping with domain-specific conceptualizations, medicine is a field that has invested a tremendous amount of resources towards QoL research and tool development. Some have suggested that there is twice as much research on QoL in the medical field compared to others (Birren, Lubben, Rowe, & Deutchman, 1991), a phenomenon that is attributed to the surge in correlational research on health and QoL. Given the exorbitant costs associated with health care and old age, growing efforts have been placed on understanding variables that contribute to better (and worse) health in older adults, and which subsequently impact QoL. For this reason among others, the concept of Health-Related QoL (HQoL) has gained increased attention over the last few decades (see Moriarty, Zack, & Kobau, 2003). It should be noted that HQoL is highly specific to health-related behaviors. Given the broader psychological context of the current endeavor, this construct will not represent a central focus of the remainder of this review. For a recent review of HQoL models please see Bakas and colleagues (2012).

As a whole, this discussion points to the importance of adapting definitions and measurements of QoL to the particular population(s) of interest. In accordance with this, the next section represents a review of relevant QoL literature as it pertains to our target population, older adults.

QoL in Old Age

As described above, a universal model and definition of QoL has yet to be found. In fact, a systematic review of the literature for 1994-2006 found hundreds of definitions and thousands of measures (Halvorsrud & Kalfoss, 2007). It appears some of the variability found in the literature may not only be due to the various disciplines interested in this concept but also the myriad of populations under which QoL has been studied. Given the highly individualistic nature of QoL, some have labeled it an 'idiosyncratic mystery' (Netuveli & Blane, 2008). More importantly, these authors have emphasized the value of tailoring definitions and metrics to the population of study as a means to reduce variability and error. Since QoL potentially means something different depending on the group of study, considering group-specific approaches is necessary. The current topic of interest, aging, merits such considerations.

The growing number of older adults worldwide has undoubtedly bolstered interest for variables affecting their life experiences and well-being. As such, QoL is often used as an indicator of economic, health and social policy (Hambleton et al., 2009). It is a key variable with regards to health and social service interventions, and evidence-based clinical practices overall (Bowling et al., 2015). It seems logical that having a better understanding of QoL in the aging population would be informative for such policies and potentially reduce societal costs associated with aging (WHO, 2014).

Conceptualization of QoL in older adulthood. As indicated earlier, an important question to our topic relates to the definition of 'older adult'. It is generally agreed upon that older adulthood begins during the sixth decade of life (see WHO, 2010). Moreover, older adulthood is thought to represent a distinct phase of adulthood, and associated with transitions and shifts that are different from earlier adult years. For this reason amongst others, most researchers seem to believe that QoL in older adulthood is best represented within a multidimensional framework that includes physical, emotional and social domains (Brown, Bowling, & Flynn, 2004; Halvorsrud & Kalfoss, 2007). Evidently, this framework should include indicators that are specifically relevant to older adulthood and that are potentially different from other stages of life. Yet, as mentioned before, although QoL is relevant to numerous contexts, its presence in the health and medical sciences dominates that in other fields (Fernández-Ballesteros, 2011). That is, the majority of research on QoL in older adults is medically-grounded and has inspired a focus on HQoL. This trend has even been labeled as 'health reductionism' and said to affect the conceptualization and empirical definition of QoL (Fernández-Ballesteros, 2011). Focusing on health-related features of QoL only addresses one side of this construct and thereby neglects other aspects important to older adulthood. Although medical status can impact independence and satisfaction over one's life, it is certainly not the only factor that influences QoL in older adults.

Searching for a definition and conceptualization of QoL in older adulthood. Credit should be given to HQoL-focused research for generally defining this construct within the unique context of aging. Aside from the health and medical fields, unfortunately, many aging researchers do not define QoL (Dijkers, 2007). In a 2007 empirical review, Halvorsrud & Kalfoss found that only 13% (six studies) of the studies between 1994-2006 defined the conceptual framework of QoL for older adults. Not surprisingly, variability was observed among those studies that did define QoL. One article, for instance, emphasized the bidirectional relationships between physical health, sense of coherence, and illness (congruent with HQoL; Low & Molzahn, 2007). Another (Grundy, & Bowling, 1999) described the connection between successful aging and QoL broadly, and in line with Maslow's theory (1954); that is, contingent on the satisfaction of human needs, life satisfaction and happiness. While, finally, some have underscored the subjective aspects of QoL such as possessing a sense of well-being and self-worth appraisal (Sarvimäki & Stenbock-Hult, 2000).

Of note, although subjective well-being only represents one aspect of QoL, some have suggested that, unlike some other aspects of QoL, it remains relatively high throughout older adulthood. The Paradox of Aging (see Samanez-Larkin et al., 2014 for a recent discussion) proposes that despite multidimensional age-related losses, adults tend to prioritize well-being and efforts put toward maintaining it as they get older. Similarly to the Socioemotional Selectivity Theory described earlier, this emphasizes the relative strength around emotional regulation that many older adults seem to possess. This could serve as a protective factor for some aspects of QoL in older adulthood (e.g., the emotional impact of late-life illnesses).

In any case, the prevailing and notable disparity across the studies that do make an effort to define QoL further highlights the confusion inherent to the conceptualization of this construct in older adults. This is also in line with global limitations not specific to aging but generally applicable to QoL research. Although it is generally understood that QoL is associated with unique features at various stages of life, including older adulthood, it appears this is often not well clarified and/or outlined, nor are there agreed-upon taxonomies.

Some have suggested that the biggest obstacle to reaching such consensus is the objective-quantitative approach many researchers take to define QoL (Levasseur, St-Cyr, Tribble, & Desrosiers, 2009). Solely assessing empirically observable or measureable entities, just like restricting QoL appraisal to health-related variables, is perhaps insufficient and results in disagreement. Levasseur and colleagues (2009) suggested that using a more subjective stance, where human functioning components in areas of cognitive and emotional functioning are assessed is more appropriate. Perhaps, this could be particularly important for QoL in older adults. In a review of QoL conceptualizations, Brown and colleagues (2004) noted that it is important to ask older individuals what they believe are valid indicators of QoL. They found that older adults specifically identified certain factors as crucial to their QoL, such as independence, relationships, finances, health, spirituality, and quality of institutional care. In a similar inquiry, others (i.e., Gabriel & Bowling, 2004) found that older adults identified social relationships, comfortable houses, good public services, optimism, positive attitude, contentment, active engagement in social activities, good health, and financial security associated with independence, to be crucial to QoL. It seems a conceptualization encompassing both broad and specific domains, as well as objective and subjective indicators of QoL, as supported by the WHO, is likely the most appropriate approach to understanding and assessing this construct in older adults.

As outlined so far, effectively identifying an explicit definition of older adulthood QoL is problematic. Nonetheless, many have been successful in identifying particular factors that may be unique to this stage of life.

Settling on a taxonomy of QoL in older adulthood. A helpful classification system outlining the most common components of QoL in old age was created by Fernández-Ballesteros (2011) in a review of problematic issues associated with QoL definitions and conceptualizations in older adults. Following Brown and colleagues' systematic review (2004), this author classified the multifaceted components associated with QoL most frequently found in the literature with the intention of providing the most simple and comprehensive taxonomy. According to this model, QoL components are classified as contextual (population-based) or individual and according to their objective or subjective nature. Demographics, physical, economic, social, and health factors, legislative equality, and disability were identified as contextual and objective; whereas collective and social stereotypes such as ageism were identified as contextual and subjective. Demographics, physical, economic, social, and health factors, functional ability, ADLs, and physical fitness were classified as individual and objective; whereas well-being, life satisfaction and other subjective perspectives, as well as personal appraisal of one's own and others' conditions was classified as individual and subjective. This model serves as an example of the ideal parsimonious approach to measuring QoL comprehensively and adequately in later stages of life.

Three crucial conclusions were noted by Fernández-Ballesteros (2011) and are worth mentioning in this discussion of older adulthood QoL. First, the author argued that while subjective ratings of QoL are important to our understanding of this construct and are relevant to older adults, measuring correlations between subjective ratings and actual QoL is challenging. That is, measuring and quantifying subjective aspects of QoL is rather challenging, and is potentially insufficient to accurately represent QoL in isolation from, namely, objective characteristics. An integrated construct capturing both types of characteristics seems more appropriate. As captured by Levasseur and others (2009): “[QoL] is difficult to estimate quantitatively because it has a deep meaning as well as an intrinsic psychological dimension associated with the meaning of life and essence of the person.” (p.e92). Second, and similarly, reducing QoL to one of its facets (e.g., HQoL) is likely to lead to misinterpretations; that is, translating specific aspects of QoL to an individual’s broader context may lead to misleading conclusions regarding overall QoL, thus the importance of having multiple indicators. Third, Fernández-Ballesteros (2011) noted that limiting measurement of QoL to self-reports may result in methodological reductionism, which is obviously susceptible to biases. Informant reports, for instance, can represent a useful addition to its assessment. Again, a comprehensive and multifaceted taxonomy of QoL in older adulthood is crucial and should consider these conclusions.

All in all, the literature above makes a clear point about the complex and unique nature of QoL as it relates to older adulthood. An integrative approach of QoL, akin to that argued for in the context of EFs, seems important. Such an understanding is also crucial to evaluating the specific predictors and trajectories of QoL in older adulthood. The next section will discuss the relevant literature, bearing these measurement challenges in mind.

Indicators and trajectories of QoL in older adulthood. So far, it seems quite clear that defining and measuring QoL in the later stages of life is accompanied by many concerns and challenges. While acknowledging that there is no gold standard regarding the assessment of this construct in this population, an abundance of studies emphasizing various aspects of QoL age-related changes exist. These findings are relevant to the current topic; for instance they may inform the overarching inquiry targeting interactions between higher-order cognition and QoL changes in old age.

***Global QoL aging-effects*.** Not surprisingly, different studies have highlighted different aspects of QoL. Some studies have focused on global age-related changes (i.e., whether QoL increases or declines in old age as a whole). The English Longitudinal Study of Ageing (ELSA; Netuveli, Wiggins, Hildon, Montgomery, & Blane 2006), for example, found that QoL ratings increase after the age of 50, peaking at age 68, after which point they start to decline. The authors noted that QoL ratings only significantly decrease after the age of 86 compared to what is observed before 50, suggesting preservation of some QoL aspects during the 68-86 year old decline period. Interestingly, ELSA revealed greater variability in QoL levels with older age, suggesting that individual differences in aspects that affect QoL become more prominent with old age (e.g., perceiving a poor financial situation, depression, functional limitations attributable to longstanding illness, and limitations in mobility).

Also relevant to the global appraisal of QoL aging changes, the WHO (2014) recently addressed some potential issues with the aging population and the need to focus on improving QoL in older adults. They suggested that as life expectancy increases, QoL threats multiply (e.g., increased prevalence of chronic medical conditions with older age). This, again, points to the possibly heightened sensitivity of late adulthood to decreased QoL. They discussed strategies expanding beyond health care, inferring that this threat to QoL reaches beyond HQoL factors. Thus, the WHO emphasized the potential for maintenance of QoL in older adults, in the context of a booming aging population.

Overall, looking at QoL as a whole seems to provide important information about the global trajectory of this construct from older to late adulthood. Thus far, the available evidence suggests that there are reasons to be optimistic about at least partly maintaining QoL later in life at the aggregate level, which is consistent with the Paradox of Aging (Samanez-Larkin et al., 2014). Of note however, as we reach the far end of the lifespan it seems we may be more vulnerable to QoL threats, which may comprise certain aspects of this appraisal. Nevertheless, with the growing aging population, increased resources have been allocated to studying predictors and interventions of QoL, which underlines the significance of well-being in older adults for society.

***Specific QoL aging-effects*.** Adapting to changing life circumstances, exerting control over one's environment, and possessing resilience bolstered by social support and engagement, are individual factors that have been found to correlate with better QoL in old age (Netuveli & Blane, 2008). Enjoying highly appraised social relationships has been said to specifically act as a preserving factor for QoL even in the face of chronic illnesses. Likewise, confiding, intimacy and companionship, which are purportedly predictors of emotional support, have been suggested to have moderate to strong beneficial effects on QoL in older individuals (e.g., Kleinpell & Ferrans, 2002; Tang, Aaronson, & Forbes, 2004). Congruent with this, increased emotional support is linked with higher QoL in older adults, compared to increased functional support and decreased independence, which are associated with reduced QoL (Reinhardt, Boerner, & Horowitz, 2006). Some have found a significant relationship between psychological well-being and subjective ratings of QoL in older adults; namely, how older individuals rate their sense of efficacy, self-esteem, autonomy, and coherence can mediate the impact their health status has over their QoL (Low & Molzahn, 2007). Conversely, others have noted that despite changes in ADLs and independence, some older adults can maintain good QoL due to spirituality (e.g., Baker, 2003; Tanyi, 2002) and analogously, finding/having life meaning (e.g., Richard, Laforest, Dufresne, & Sapinski, 2004; Tang et al., 2004). External variables such as desirability of living situation, few barriers to physical activities in one's environment (related to independence) and financial resources have also related to preserved and/or enhanced QoL later on (e.g., Bowling, Banister, Sutton, Evans, & Windsor, 2002; Richard et al., 2004).

Overall, similar to the investigation of a global age-related trajectory regarding QoL, research targeting specific contributors of change undoubtedly shed light on the potential moderators of QoL in older adults. Also, the research described herein seems to reinforce the multifaceted nature of QoL. Given the unique contributions of these different types of inquiries to our understanding of such aging processes, it seems natural to consider an approach that comprises both global and specific aspects of QoL.

Global and specific QoL aging-effects. Nation-wide inquiries including large samples have allowed researchers to survey the unique predictors of QoL and its broader course with regards to aging. The following study is a meaningful example of this type of endeavor.

A study by Baernholdt et al. (2012) used secondary data from a national survey (the National Health and Nutrition Examination Survey in the United States) designed to assess the prevalence of major diseases and risk factors for diseases from 2005 to 2006. The primary study examined a nationally representative sample of roughly 5000 individuals every year. The secondary data was utilized to investigate the link between three dimensions of QoL (i.e., HQoL, emotional well-being, and social functioning), needs, and health behaviors in 991 adults of ages 65 and older. At the global level, these authors found QoL to be generally high in older adulthood. Additionally, they observed that only certain factors were associated with a decrease in all three dimensions of QoL: lower scores on the Activities of Daily Living scale, presence of memory problems, and higher levels of depression. In terms of QoL subdomains (i.e., HQoL, emotional well-being and social functioning) distinct predictors were found. Poorer HQoL, for instance, was associated with lower education, lower ADL scores, and increased depression;

higher social functioning was related with increased age, female gender, African-American background, being married, higher education, better ADL scores, absence of memory concerns, and increased utilization of health care services; and finally, inferior emotional well-being was associated with Hispanic and African-American backgrounds, lower ADL scores, increased depression, and lower physical activity.

The added value of investigating both global and specific contributors to aging and QoL seems evident here; that is, this large survey successfully sheds light on broad trends and narrow factors that affect age-related changes in QoL.

Moreover, another wave of ELSA provided further support for multifaceted age-related changes in QoL using the CASP-19 and predictors of change across older adulthood. Zaninotto, Falaschetti, and Sacker (2009) looked at QoL ratings in a sample of 11,392 individuals aged 50 and above over four years, and using Latent Growth Curve models. Baseline QoL ratings were found to be better in younger than in older adults, which seemed to be accentuated over the course of the study (i.e., steeper declines for adults in the older ages, over 65 years of age). QoL ratings were also significantly worse in males than in females and for those without any educational attainment. Rate of decline was not influenced by gender or education. Specific predictors associated with declining QoL included greater symptoms of depression, functional limitations in ADLs linked with chronic illnesses, lower financial status, not perceiving positive support from family members and friends, and having fewer intimate relationships. Conversely, cohabiting with someone seemed to be associated with better QoL with age, with a gender effect favoring men but not women. This gender effect was attributed to the prevalent caregiving role many women take on later in life, which is generally not correlated with better QoL and can in fact be associated with greater stress and potentially diminished QoL. Altogether, indicators of psychosocial circumstance in later life appeared to be significant contributors to age-related changes in QoL. The authors argued that manipulating such variables may represent a viable intervention for maintaining or improving QoL in older adults.

Development of the WHOQOL-OLD module. The WHO put together a work group to investigate the adequacy of their existing QoL measures in older populations over a decade ago (Power et al., 2005). This project was concurrently initiated for the development of an age-appropriate add-on module for their notorious WHOQOL questionnaires (i.e., WHOQOL-BREF or the WHOQOL-100).

The WHO orchestrated the development of focus groups with older adults, caregivers, and professionals working with older adults in 22 centers worldwide. These groups generated items thought to be missing from the WHOQOL measures for the assessment of QoL in older adults, which were subsequently tested among 7400 respondents from the centers. Following the creation of new items, they used classical and modern psychometric methods, field trial studies, cross-cultural validation and reevaluation of the new items. The outcome was the creation of a 24-item, 6-facet module, the WHOQOL-OLD, recommended as an add-on to the WHOQOL-BREF or the WHOQOL-100, for assessment of QoL in older adult populations. Using confirmatory factor analysis, Power and colleagues (2005) revealed a six-factor model that showed both unity and diversity of the QoL construct; that is, their analyses suggested one higher order factor (i.e., global QoL construct), as well as six distinct latent variables. These six factors are: sensory abilities, autonomy, past, present, and future activities, social participation, death and dying, and intimacy. The 'sensory abilities' facet focuses on one's sensory functioning and the impact of sensory impairment on daily activities. The 'autonomy' facet considers one's perspective related to control on decision-making and control over the future. The 'past, present, and future activities' facet targets one's satisfaction with past successes and with potential future opportunities. 'Social participation' focuses on one's satisfaction of current and potential opportunities for community engagement. The 'death and dying' facet looks at one's attitude regarding end of life. The 'intimacy' facet considers companionship and love opportunities.

The WHOQOL-OLD endeavor was a sensitive response to concerns relevant to the growing aging population and risks associated with diminished QoL later in life. This project was deemed a necessary addition to the existing WHOQOL measures and the field of QoL in older adults overall, given what we know about the different faces of QoL in old age.

Since its creation, many have studied and utilized the WHOQOL-OLD. Peel, Bartlett, and Marshall (2007) for instance, tested the psychometric properties of the WHOQOL-OLD against a generic health-related QoL measure, and a commonly used QoL measure, the SF-12, as well as tools of psychological and physical well-being. They found that he WHOQOL-OLD had good reliability and validity and showed greater appeal for measuring QoL in older adults compared to the other measures due to the absence of floor and ceiling effects, a distribution of scores that does not require any transformation (compared to other tests where data has to be transformed to derive the summary scores), and superior test-retest reliability. The authors suggested that this is likely due to the specific aging context within which this measure was developed; that is, the WHOQOL-OLD was created specifically to assess older adult populations, as opposed to other measures that were intended for the general adult population.

Numerous studies supporting the different cultural/language versions of WHOQOL-OLD have also been published. These studies have shown good reliability and validity and further absence of floor and ceiling effects (Chachamovich, Fleck, Trentini, & Power, 2008;

Eser, Saatli, Eser, Baydur, & Fidaner, 2010; Halvorsrud & Kalfoss, 2007; Lucas-Carrasco, Laidlaw, & Power, 2011).

All in all, this measure seems to remedy measurement and conceptualization concerns such as those expressed previously, by providing a comprehensive and sensitive measure of QoL with factors both united (correlated), diversified (distinct) and relevant to the context of aging. Again, such an empirical endeavor seems highly pertinent given the growing aging population and the multifaceted nature of QoL as it relates to older adults.

Investigating the Relation Between EFs, QoL, and Aging

A question left unanswered. The vulnerability of the anterior regions of the brain to the effects of aging and the associated repercussion on EFs were discussed in this dissertation. Measures and factors related to QoL in older adults were also explored. Moreover, the association between cognitive aging and lowered QoL was mentioned, and elucidating the potential moderating role of QoL over complex cognitive skills (i.e., EFs) in old age was proposed. Hence, drawing on the topics that have been presented so far, a question that arises now is: *What are the relations between aging, EFs and QoL?*

It was suggested above that QoL varies based on the integrity of the executive system in various populations. The nature of this relationship was deemed unclear, and evidence supporting this claim mainly seemed to target abnormal populations (e.g., adults with schizophrenia, epilepsy, Parkinson's Disease). Nevertheless, based on these findings, it was also argued that QoL and factors underlying this construct could potentially moderate the extent of age-related decline normally associated with EFs in old age. QoL was proposed to potentially act as a protective factor over age-related EFs declines. In keeping with this, better or worse sensory abilities, autonomy, past, present, and future activities, social participation, death and dying, and intimacy (WHOQOL- OLD factors) may possibly buffer or enhance the extent of normative age-related differences associated with EFs in older adults. Due to the known impact of aging over EFs, the variability in and importance of QoL in older adulthood, and the impact of life circumstances over cognitive abilities, it seems reasonable to wonder *if and how QoL moderates the magnitude of EFs differences in old age*.

Existing support for the moderating role of QoL over EFs. Empirical findings implicitly supporting such a relationship seem to exist. In her recent review of EFs, Diamond (2013) repeatedly discussed the apparent moderation association between factors pertinent to QoL over higher-order cognition: "EFs and prefrontal cortex are the first to suffer, and suffer disproportionately, if something is not right in your life. […] You can see the deleterious effects of stress, sadness, loneliness, and lack of physical health or fitness at the physiological and neuroanatomical level in prefrontal cortex and at the behavioral level in worse EFs (poorer reasoning and problem solving, forgetting things, and impaired ability to exercise discipline and self-control)." (p. 153). Diamond stated that this vulnerability is more prominent for EFs than any other cognitive function. In essence, the author's depiction of the susceptibility of PFC functions to lifestyle variables seems to highlight the potential moderating effect of QoL over EFs; that is, factors subsuming QoL undoubtedly have an effect over EFs throughout life. Given what was discussed in the first portion of this dissertation, this effect may arguably also be true and particularly relevant for EFs in older adulthood.

As part of the seminal Victoria Longitudinal Study, de Frias and Dixon (2014; see also Small, Dixon, McArdle, & Grimm, 2012) provided evidence for the moderating role of lifestyle engagement (i.e., frequency of engagement related to cognitive, physical, and social activities) over the association between cognitive status (i.e., cognitively elite, cognitively normal, and cognitively impaired) and EFs in older adults. Numerous important findings were generated from this line of inquiry. They found that baseline social engagement moderated cognitive status differences in EFs, such that cognitively impaired adults with high social engagement had EFs equivalent to cognitively normal adults. Additionally, engagement in physical activities was found to significant predict maintenance of cognitive status over time, such that cognitively impaired adults who had higher levels of physical activity were more likely to improve their EFs longitudinally compared to more sedentary counterparts. Finally, engagement in cognitive activities was found to be a significant predictor of the preservation of EFs in the cognitively elite group. These results further suggest that lifestyle variables such as the ones discussed here, and which are all relevant to QoL (although not defined as QoL factors in the study above), can contribute to preserving or worsening EFs later in life.

A gap to fill. Extensive literature targeting EFs and aging, and QoL and aging, has been published to date. Still, empirical evidence of the interaction between EFs, QoL and aging, has not yet been offered. Given the present review of the relevant literature, the significant growth in the older adult population, and the possible benefits associated with uncovering this complex relationship, we believe this gap in the literature should now be addressed.

Current Study

The aim of the current study was to examine the possible moderating role of QoL over age-related EFs differences. More specifically, the influential taxonomy of EFs proposed by Miyake and colleagues (2000, 2012) and the work of the WHO on QoL in older adults (Power et al., 2005) were used to investigate interactions between distinct EFs (i.e., Shifting, Updating, and Inhibiting) and QoL components obtained via self-report (i.e., sensory abilities, autonomy, past, present, and future activities, social participation, death and dying, and intimacy) in older adults. To this end, six computerized tasks of EFs and the WHOQOL-OLD were utilized with a sample of 102 older adults to study age-related differences in EFs and QoL. As described shortly, a moderation analysis was conducted to assess if QoL moderates the empirically-supported relationship between age (independent variable [IV]) and EFs (dependent variable [DV]). Overall, it was hypothesized that QoL does moderate the relationship between age and EFs (discussed in more detail in the methods section). In addition, based on the previously discussed prominent theories of EFs, an integrative approach to aging and EFs was taken, where *the processing speed theory* (Salthouse, 1996), *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988; Darowski et al., 2008; Hasher et. al, 2007), and *the dedifferentiation hypothesis* (Garrett, 1946) were considered. A series of multiple regression analyses were conducted to evaluate age-related differences in EFs and the contribution of EFs theories.

Methods

Participants. 102 community-dwelling, healthy, older adults of ages 60 and over (the United Nations' agreed cutoff to refer to the older population; WHO, 2010) participated in this study (M = 73.108 years; age range 60 - 94), with an even gender distribution. A G*Power analysis suggested that the sample size was adequate to ensure a minimum power of 0.80 with an alpha level of .05. Participants were recruited from local recreational centers, retirement homes, the University of Victoria, and other community-active establishments in the city of Victoria (British Columbia, Canada) by this dissertation author. Eligibility for participating in the study was based on the following conditions: no history of significant vision problems (corrected vision was acceptable; e.g., prescription glasses), neurologic disorder (e.g., stroke, epilepsy, chronic migraines), neurodegenerative disorder (e.g., Alzheimer's disease, Multiple Sclerosis), or traumatic brain injury. Additionally, individuals who participate in weekly (or greater) recreational drug use (other than tobacco and alcohol) were excluded from the study. Approval for the study was obtained from the University of Victoria Human Research Ethics Board in accordance with the Canadian Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Procedure

All participants were asked to provide written, informed consent and to complete a brief screener questionnaire (see Appendix A). They were asked to complete six tasks measuring the three widely-supported EFs (i.e., Shifting, Updating, and Inhibiting). The tasks were inspired from Miyake and colleague's seminal work (2000). All tasks were administered on a computer requiring very basic computer skills (i.e., pressing the space bar, two letter keys, and number keys). The font for the instructions and task stimuli was enlarged significantly to accommodate various vision levels and needs. The order of the tasks was counterbalanced to manage potential fatigue effects. Participants were also asked to complete a paper version of the WHOQOL-OLD as an add-on to the WHOQOL-BREF. The specific tasks and questionnaire are described next. Total participation time was approximately 1.5 hours (approximately 5-10 minutes for the screener questionnaire, 30-45 minutes for the EFs tasks, and 45 minutes for the QoL measures). All testing was done at the Centre on Aging at the University of Victoria.

Pilot testing. The history and QoL questionnaires, as well as the EFs tasks were piloted on 18 participants. Previous studies have shown that this can be a valuable step when working with older adult populations to identify the need for modifications, especially related to task instructions (e.g., when using tasks designed for college students with older adults; Crevier-Quintin, 2013). No concerns were raised during pilot testing and there was therefore no need to make any changes to the measures or administrative procedures outlined herein.

Measures.

Evaluation of EFs. As it will be specified below, two outcome variables or indicators were produced for all six EFs tasks and used for our analyses: a) response accuracy and b) reaction time (RT). A global composite EFs accuracy score was also computed. Accuracy represents correct answers, whereas RT represents the elapsed time between the presentation of a stimulus and the associated executive-behavioral response. This is in contrast to processing speed, which was also measured to evaluate one of the theories and which is typically involved when a simple behavioral response outside of the realm of executive abilities is required (e.g., pressing the space bar every time a stimulus, any stimulus, appears on the screen). This distinction will be described in further details in the following paragraphs.

Two tasks were used to evaluate **Shifting**:

A **Local-Global** task was used as an indicator of Shifting. Of note, this task was used in the work of Miyake and colleagues (2000). Participants were presented with 'Navon figures' (geometric shapes possessing both local and global qualities; Navon, 1977; see Figure 1). They were then asked to press different number keys depending on the color of the figures, to indicate whether either the local or global geometric figures represented a circle, a triangle, or a square. Participants had to 'shift' their attention back and forth between stimuli properties, to identify whether a local or global figure was displayed. There were three trial blocks tapping onto either global or local cues exclusively (first two blocks; 30 stimuli each), and randomly presented both global and local cues (third block; 100 stimuli). To account for RT in this task, 'shift costs' (a.k.a. 'switch costs', Huff, Balota, Minear, Aschenbrenner, & Duchek, 2015; Rogers & Monsell, 1995) were calculated by averaging the difference in RT between the non-executive blocks (first and second) and the executive block (third and last), requiring a 'shift' in attention (Frazer, 2012). An average of these 'shift costs' (i.e., RT) and response accuracy were used as indicator variables for Shifting.

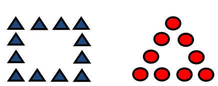

Figure 1. Example 'Navon figures' (Navon, 1977), used in the Local-Global task.

The **Number-Letter** task (Rogers & Monsell, 1995) was used as another indicator of Shifting. This task was also used in Miyake and colleagues' original work (2000). For this task, a number-letter pairing was displayed (e.g., 4A) in one of four quadrants on the computer screen. If the stimulus appeared in the lower half of the screen (bottom two quadrants), participants were asked to indicate whether the number was even or odd. If the stimulus appeared in the top half of the screen (top two quadrants), participants were asked to indicate whether the letter was a vowel or consonant. Participants thus had to 'shift' their attention back and forth between the stimuli, location, and appropriate responses. There were three trial blocks. Stimuli location alternated between either the bottom (first block; 20 trials) or top two quadrants (second block; 20 trials), or rotated in a clockwise manner in all four quadrants (third block; 100 trials). An average of 'shift costs' (i.e., RT) and response accuracy were used as indicator variables for Shifting.

Two tasks were used to evaluate **Updating**:

The **Letter Memory** task (see Morris & Jones, 1990) was used as an indicator of Updating. This task was also used in Miyake and colleagues' work (2000). For this task, a running sequence of letters randomly varying in length (7-12 letters) was displayed on the computer screen, one letter at a time. Participants were asked to remember the last four letters of the series. For instance, if participants were presented with the letters 'A, D, Z, B, G, H, R, C', they had to rehearse the last four letters and update them as they appeared on the screen. At the end of the sequence, when prompted, participants would have typed 'GHRC' (the last four letters). Participants were prompted to recall these target letters five times during the task (i.e., five trials, four letters per trial, 20 letters in total). The total number of letters recalled correctly and in the correct order over the course of the task (accuracy) as well as average RT were used as indicators of Updating WM.

The **Keep Track** task (Yntema, 1963) was used as another indicator of Updating. This task was also used in Miyake and colleagues' work (2000). For this task, participants were presented with the names of either three or four stimulus categories (animals, vegetables, etc.). Then, 15 words were presented randomly, one at a time, while the names of the categories remained on the screen (see Figure 2). Some of the words represented examples from each target category, whereas others did not. Participants were prompted to remember and type the last word that was presented and that belonged to each target category (three or four target words in total), at the end of each trial block. There were three trial blocks of 15 words each (one block with three categories; two blocks with four categories). The total percentage of words recalled correctly (accuracy) across the task (out of 11) and RT were used as indicator variables for Updating.

a. b.

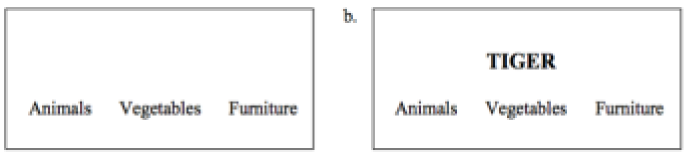

Figure 2. Example screenshots from the Keep Track Task: a) the initial ‘category screen’, b) a sample presentation screen.

Two tasks were used to evaluate **Inhibiting**:

A **Go/No Go** paradigm (Donders, 1969) was used as an indicator of Inhibiting. This task was also used in Miyake and colleagues’ work (2000). Participants were presented with a single letter in the center of the computer screen at a rate of approximately 1 word per 1,400 msec. There were two trial blocks consisting of the ‘go’ trial (i.e., pressing the spacebar as fast as possible whenever a letter appeared on the screen) and the ‘no-go’ trial (i.e., pressing the spacebar as fast as possible whenever a letter appeared on the screen while inhibiting any response to the letter J). Response accuracy and RT for the ‘no-go’ trial (i.e., the “executive” trial block) were used as indicators of Inhibiting. Please note that RT on the ‘go’ trial block was used as an indicator of simple processing speed. More specifically, the first block allows for the development of a prepotent response and is not thought to involve executive abilities, unlike the second block, which requires inhibiting the prepotent response.

A **Stop Signal** paradigm (Logan, 1994) was used as another indicator of Inhibiting. This task was also used in Miyake and colleagues' work (2000). For this task, words belonging to one of two categories (animals or non-animals) were displayed in the middle of the screen. For the first block, participants were asked to sort words by pressing one key for animals, and another key for non-animals. Doing so fostered the development of a prepotent response. For the second trial block, participants were asked to refrain from pressing any key when a visual 'stop signal' appeared on top of the word, shortly after the presentation of the word. Stop signals appeared at five different delays (occurring equally often and at random): 50 ms, 100 ms, 150 ms, 200 ms, and 250 ms after the onset of the word. Response accuracy and RT for the second block (i.e., the "executive" trial) were used as indicators of Inhibiting. Similar to the Go/No Go paradigm, RT on the first trial block was also used as an indicator of simple processing speed, as it will soon be described.

***Evaluation of EFs theories*.** The multifaceted nature of EFs was discussed and some of the most prominent theories of reorganization across adulthood were described. It was suggested that each theory uniquely contributes to our understanding of the aging of EFs, and that evidence supporting and also contradicting each of the theories exists. It was also proposed that given the conflicting evidence and inherent complexity of cognitive aging, an integrative approach considering each of these theories should be used. To deepen our understanding of age-related EFs differences in later life, the current study aimed to assess the potential contribution of each theory to the findings sought herein. Thus, EFs were not only considered from a perspective derived from the work of Miyake and colleagues (2000), but also from research based on the processing speed theory (Salthouse, 1996), the inhibition deficit theory of cognitive aging (Hasher & Zacks, 1988), and the dedifferentiation hypothesis (Garrett, 1946).

Briefly, **the processing speed theory** (Salthouse, 1996) argues that cognitive aging results from slowed processing speed. EFs are said to decrease in older adulthood due to a general slowing of the underlying abilities necessary to execute these more complex functions. A simple measure of RT was used as an indicator of processing speed and to account for the processing speed theory in this study. A mean RT score was calculated for the first block of both the Go/No Go and Stop Signal tasks. This was deemed appropriate as the first block for each of these tasks inherently represents a simple measure of RT and does not involve higher-order skills (i.e., simply pressing the appropriate key as fast as possible without relying on EFs).

The inhibition deficit theory of cognitive aging (Hasher & Zacks, 1988) suggests that a negative correlation between age and performance on inhibitory tasks exists. More importantly, declining inhibition has been suggested to be the principal determinant of age-related cognitive deficits (Bell et al., 2008; Darowski et al., 2008; Hasher et al., 2007; Hasher & Zacks, 1988; Kane et al., 1994; Pettigrew & Martin, 2014; Stoltzfus et al., 1993). Inhibiting was one of the primary EFs that were evaluated as part of this study.

Finally, **the dedifferentiation hypothesis** (Garrett, 1946) proposes that, as we age, our cognitive abilities become increasingly correlated. According to this hypothesis, and building from the concepts of unity and diversity described previously (Teuber, 1972), older adulthood would be marked by more cognitive unity (i.e., less differentiation among cognitive functions) compared to the rest of adulthood (e.g., see de Frias et al., 2007). The multidimensional measurement of EFs embedded in this study allowed for consideration of this theory; no additional tasks were required.

Evaluation of QoL. The WHOQOL-OLD is a 24-item measure that was used to indicate QoL. There were four items for each of the six facets (i.e., sensory abilities, autonomy, past, present, and future activities, social participation, death and dying and intimacy), which were rated on a five-point Likert scale. The mean of the summed answers (ranging from one to five) represents the score for each facet. The mean of the summed facet scores represents total QoL (ranging from one to five). Higher scores indicate better QoL and lower scores suggest poorer QoL.

The add-on module was used in conjunction with the 26-item questionnaire, the **WHOQOL-BREF** (Skevington, Lotfy, O'Connell, & The WHOQOL-Group, 2004; WHOQOL Group, 1998). Of note, it is required by the WHO that the WHOQOL-OLD be used in conjunction with, as an add-on module to, either the WHOQOL-BREF or WHOQOL-100. The WHOQOL-BREF taps onto four QoL domains: physical (physical health and functional status), psychological (psychological well-being), social relationships (personal relationships and social support), and environment (living circumstances including access to services). It produces a score for each domain. These scores correspond with the WHOQOL-OLD approach described above. Comparable to the WHOQOL-OLD, it has good cross-cultural applications, validity, internal consistency, and reliability.

In total, participants completed 50 questions related to their QoL (24 for the WHOQOL-OLD and 26 for the WHOQOL-BREF; please see Appendix B).

Aims and Hypotheses

The review of literature demonstrated absence of published research targeting a combined examination of EFs, QoL and aging. To address this gap, the first main aim was to evaluate age-related differences in EFs within the context of previously-stated and relevant EFs theories, and second, to evaluate the potential moderating role of QoL over age-related differences in EFs.

Evaluating age-related differences in EFs and the contribution of EFs theories. In order to address the posited moderating role of QoL over EFs, the hypothesized age-related differences in EFs had to be confirmed. The first goal of the present study was thus to utilize the aging theories described herein as a framework for evaluating performance differences on tasks of EFs in our sample.

In evaluating *the processing speed theory* (Salthouse, 1996), based on the literature mentioned earlier it was hypothesized that even when processing speed was accounted for, significant age differences in EFs would be found. More specifically, the proportion of variance accounted for by age related to the performance on EFs tasks would be significant, even when processing speed, supposedly a mediator of cognitive aging (Salthouse, 1996), was controlled for. Again, few studies have looked at the mutual relationship and effect of processing speed over EFs in old age, and even fewer have included a multidimensional measurement of EFs. For those who did (e.g., Albinet et. al, 2012 looked at Shifting, Updating, and Inhibiting), EFs and processing speed were found to share mutual variance while being independently affected by aging. Hence it was expected that the current study, which includes a multifaceted conceptualization of EFs, would reveal similar findings.

Further, considering *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988) involved an evaluation of age-related differences for all indicators of EFs (related to Shifting, Updating, Inhibiting, and global EFs). It was hypothesized that older age would adversely impact task performance for all executive indicators; that is, younger participants were expected to perform better across EFs tasks compared to older counterparts. According to this theory and the available literature, age was expected to affect the four indicators of Inhibiting above and beyond other indicators; that is, tasks tapping onto Inhibiting would show significantly greater age-related effects compared to tasks meant to represent Shifting and Updating. Congruent with the previous hypothesis, this effect was expected to be present even when processing speed was accounted for.

Next, in evaluating *the dedifferentiation hypothesis* (Garrett, 1946), it was hypothesized that associations among EFs tasks would not reveal significant age-effects. As outlined earlier, the literature on this hypothesis is mixed. And, although earlier studies seemed to support it, at present, comparable evidence appears to be scarce. Also, as noted above, using a comprehensive model that upholds a multidimensional definition of EFs is crucial to evaluating dedifferentiation with age. This is not typically found in the literature. Overall, the hypothesis of dynamic dedifferentiation with old age (progressively increasing correlations amongst cognitive functions) was not expected to be supported in the current study. It was expected that we would find no statistically significant increased associations in performance among EFs tasks with increasing age and that indicators of EFs would be similarly cognitively diverse in our youngest and oldest participants.

Evaluating the moderating role of QoL over age-related differences in EFs. The overarching aim of this study was to investigate the potential moderating role of QoL over the well-known effect of age on EFs. It was hypothesized that QoL (i.e., 11 QoL domains) would moderate the relationship between age and EFs (i.e., 13 indicators of EFs) in our participants. Accordingly, it was expected that lower QoL scores on the WHOQOL-OLD (i.e., poorer estimated QoL) would enhance the detrimental impact of older age on the EFs indicators. Similarly, it was expected that higher QoL scores on the WHOQOL-OLD (i.e., higher estimated QoL) would buffer the negative effect of older age on EFs. Altogether, it was hypothesized that better or worse QoL would protect against or exacerbate the degree to which older age negatively impacts EFs, respectively.

Data Analysis

Evaluating age-related differences in EFs and the contribution of EFs theories. To assess the amount of variance due to processing speed on the age-related variance in each indicator of EFs, a series of hierarchical multiple regression analyses were conducted (see Albinet et al., 2012 for similar statistical procedures; Tabachnick & Fidell, 2001, 2007). Consistent with this study's first aims, these analyses were aimed to help determine if the hypothesized age-related variations were at least partly due to age differences, and to evaluate the theory that cognitive aging results from one global mechanism: slowed processing speed (*the processing speed theory*; Salthouse, 1996).

To this end, step 1 of the hierarchical regression analyses predicted EFs performance (DVs) from processing speed (IV). Then, step 2 predicted the additional contribution of age (IV), which was hypothesized to still be significant after controlling for processing speed. That is, the model hypothesized that increasing age would be associated with poorer performance across EFs tasks above and beyond the contributions of processing speed. Analyses were conducted to examine age-related differences for each DV, (a) looking at a global EFs composite score, and (b) each of the two outcome variables for each of the three EFs components (i.e., looking at both accuracy and RT for each of the 6 tasks). Altogether, hierarchical regression represented an ideal approach to assess the effect of age on each executive component and to investigate how well age predicts EFs globally and for each individual EF, after controlling for the effect of processing speed. The analyses above were also aimed to assess *the inhibition* *deficit theory of cognitive aging* (Hasher & Zacks, 1988), where performance on Inhibiting tasks was hypothesized to be affected by age above and beyond other EFs tasks.

Next, to address the last theory of cognitive aging (i.e., *the dedifferentiation hypothesis*; Garrett, 1946), multivariate analysis of covariance (MANCOVA) procedures were conducted to examine the relationships among EFs as a function of age, after controlling for processing speed. These analyses tested whether performance on tasks of EFs was related similarly across ages. It was hypothesized that the relationships among EFs variables and age would not be significantly different from younger (i.e., younger participants; e.g., early 60s) to older adulthood (i.e., oldest participants; e.g., late 80s to early 90s).

Evaluating the moderating role of QoL over age-related differences in EFs. A moderation analysis was conducted to assess if level of QoL (moderator) moderates the relationship between age (IV) and EFs (DVs). As such, the final question representing the overarching aim of this study was: *Does QoL moderate the relationship between age and EFs?* A multiple linear regression analysis was conducted where age, QoL, and the interaction between age and QoL, represented the IVs of the regression, and EFs represented the DV (Baron & Kenny, 1986). This theorized effect has been suitably called a *buffering interaction* (Cohen, Cohen, West, & Aiken, 2003), where one predictor (i.e., QoL), weakens the effect (i.e., decreased EFs) of another predictor (i.e., older age). Additionally, according to the *buffering interaction*, one predictor is seen as representing a risk factor (i.e., age) over another variable (i.e., EFs), whereas another predictor (i.e., QoL) is hypothesized to represent a protective factor that moderates the negative impact of the risk factor. It was expected that a significant interaction would be found, supporting the moderation hypothesis.

Results

Data Preparation

Data cleaning and screening. Data for the EFs tasks were extracted from E-Prime, while the QoL questionnaire data were scored and coded anonymously in Excel. To detect outliers, accuracy scores and RTs for the EFs tasks and ratings for the QoL measures larger than three standard deviations (SDs) above the mean were excluded (Tabachnick & Fidell, 2001). Additionally, for the WHOQOL-BREF and -OLD domain scores to be calculated, at least six and four items per scale respectively had to be answered. For the total QoL score, participants with >20% missing data were excluded. These procedures correspond with the WHO guidelines. Outliers and missing data were identified following the screening procedures for most of the tasks. Altogether, excluded and missing data resulted in the following exclusions.

EFs tasks: for Shifting, three participants did not receive a Local-Global accuracy score and two participants did not receive a RT value, also, five participants did not receive a Number Letter accuracy score and four did not receive a RT value; for Updating, two participants did not receive a Letter Memory accuracy score and two did not receive a RT value, also, four participants did not receive a Keep Track accuracy score and five did not receive a RT value; for Inhibiting, one participant did not receive a Go/No Go accuracy score, also, four participants did not receive a Stop Signal accuracy score and four did not receive a RT value. Feedback from participants suggested that the majority of the aforementioned missing or excluded data resulted from failure to remember the instructions and to carry out the tasks. In some cases, the tasks had to be discontinued manually by the examiner as per the examinees' request, or alternatively participants reported that they would guess randomly until they reached the end of the task.

QoL measures: a domain score was not computed for the following number of participants. For the WHOQOL-BREF: one participant for the psychological domain and one for the social relationships domain. For the WHOQOL-OLD: five participants for sensory abilities, four for autonomy, four for past, present, and future activities, five for social participation, eight for death and dying, nine for intimacy, and 16 for the total score. Feedback from participants suggested that the majority of the aforementioned missing or excluded data resulted from feeling that the items/questions were not applicable to their current situation (in which case participants did not answer the questions).

Moreover, the age and QoL variables were centered to reduce potential multicollinearity effects (Cohen et al., 2003; Cohen, Cohen, West, & Aiken, 2013). This procedure is often recommended in regression; that is to center the predictors (i.e., age and QoL) so that they have a mean of 0, which allows the intercept term to be interpreted as the expected value of the DV (i.e., EFs) when the predictor values are set to their means. If age and QoL where not centered, the intercept would be interpreted when age and QoL are set to zero, which is not interpretable (i.e., age and QoL cannot realistically be equal to zero here). Also, the EFs accuracy scores were transformed into Z scores for comparison purposes. The EFs RT values did not require any transformation as they were all on the same scale (ms). Finally, assumptions regarding homogeneity of variance were satisfied for all measures based on the Levene statistic.

Descriptive statistics. 102 community-dwelling, healthy, predominantly Caucasian, older adults of ages 60 and over (M = 73.108 years; SD = 7.88; age range 60 - 94), with an equal gender distribution (50 males, 51 females, 1 missing) participated in the study. Table 1 below summarizes the descriptive statistics for the sample based on education, marital status, and illness, assessed with the WHOQOL-OLD and considered as covariates of EFs and QoL (see section on Evaluating the Role of Education, Marital Status, Illness, and Gender over EFs and QoL further below).

Table 1

Descriptive Statistics for Education, Marital Status, and Illness

		Frequency	Percent	Valid	Missing
Education Level				102	0
	Primary	0	0		
	Secondary	11	10.8		
	Tertiary	91	89.2		
	Total	102	100		
Marital Status				102	0
	Single	2	2		
	Married	71	69.6		
	Living as Married	4	3.9		
	Separated	2	2		
	Divorced	8	7.8		
	Widowed	15	14.7		
	Total	102	100		
Illness Status				101	1
	Not Ill	95	93.1		
	Currently Ill	6	5.9		
	Total	101	99		

Evaluating Age-Related Differences in EFs and the Contribution of EFs Theories

Processing speed theory. A series of correlation and hierarchical multiple regression analyses were conducted to examine the relationship between 13 indicators of EFs (i.e., two tasks per EFs component: Inhibiting, Shifting and Updating, with two outcome variables per task representing accuracy and RT, as well as one global composite EFs score), age and processing speed. It was predicted that *the processing speed theory* (Salthouse, 1996) would not be supported by our analyses and that processing speed would not significantly contribute to the regression model above and beyond the contributions of age.

Indicator of global EFs. Together, age and processing speed (combined) significantly predicted the indicator of global EFs (i.e., composite Z score for EFs accuracy for all six tasks), $R^2 = .123$, $F(2, 91) = 6.359$, $p < .005$. At the individual predictor level (see Table 2 below), only age individually significantly predicted global EFs scores, $b = -.017$, $t = -3.130$, $p < .005$. Once processing speed was taken into account, age still significantly contributed to global EFs scores; hence, processing speed did not significantly predict global EFs scores above and beyond the contributions of age. As predicted, *the processing speed theory* was not supported for global EFs.

Table 2

Regression Table for the Individual Effects of age (centered) and Processing Speed on Global EFs

		Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
Coefficients		B	Std. Error	Beta		
Global EFs						
	(Constant)	0.151	0.092		1.643	0.104
	Age	-0.017	0.005	-0.31	-3.13	**0.002**
	Speed	0	0	-0.126	-1.272	0.207

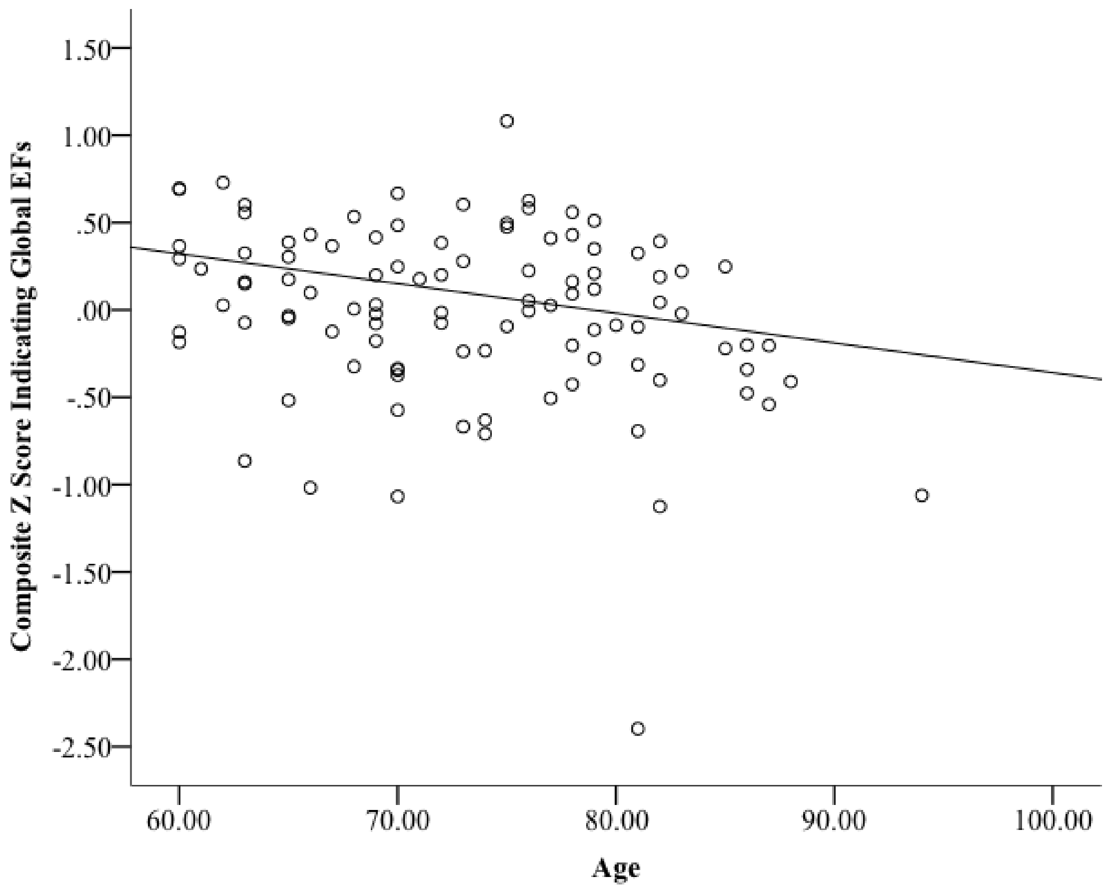

Figure 3. Scatterplot for the Effects of age on Global EFs, After Controlling for Processing Speed

Indicators of Shifting. As can be seen in Table 3, together age and processing speed (combined) significantly predicted Local Global accuracy, $R^2 = .098$, $F(2, 88) = 4.853$, $p = .01$, and RT, $R^2 = .123$, $F(2, 89) = 6.215$, $p < .005$, and Number Letter accuracy, $R^2 = .094$, $F(2, 88) = 4.588$, $p < .05$. At the individual predictor level (see Table 4), age individually significantly predicted Local Global accuracy, $b = -.027$, $t = -2.917$, $p < .005$, and RT, $b = -27.002$, $t = -2.241$, $p < .05$, and Number Letter accuracy, $b = -.028$, $t = -2.987$, $p < .005$. Processing speed individually significantly predicted Local Global RT, $b = -.602$, $t = -2.410$, $p < .05$. As predicted, *the processing speed theory* was not supported for Local Global accuracy, Local Global RT, Number Letter accuracy, and Number Letter RT.

It should be noted again that unlike other RT indicators, those utilized for the Local Global and Number Letter tasks were based on a 'shift cost' calculation. 'Shift costs' (Huff et al., 2015; Rogers & Monsell, 1995) are thought to reflect processes associated with maintaining and switching between multiple task configurations across pure (non-executive) and switch (executive) trials. The direction of the statistically significant relationship between age and Local Global RT in Table 4 and Figure 5 may at first glance appear to reflect significantly better/faster RTs with older age (i.e., a decrease in RT with age). This was not the case; rather, the computed 'shift costs' were smaller with older age. Again, 'shift costs' look at average differences in RT across blocks (requiring Shifting vs. no Shifting). Understanding this effect requires an understanding of 'shift costs' themselves as well as a closer look at the data. These results will be discussed in greater details in the discussion section (see subsection on unexpected relationships).

Table 3

Regression Table for the Combined Effects of age (centered) and Processing Speed on Indicators of Shifting

					Change Statistics				
	R	R Square	Adjusted R Square	Std. Error	R Square Change	F Change	df1	df2	Sig. F Change
Local Global Accuracy	.314	0.098	0.078	0.687	0.098	4.853	2	89	**0.010**
Local Global RT	.350	0.123	0.103	895.787	0.123	6.215	2	89	**0.003**
Number Letter Accuracy	.307	0.094	0.074	0.703	0.094	4.588	2	88	**0.013**
Number Letter RT	.198	0.039	0.017	815.574	0.039	1.796	2	88	0.172

Table 4

Regression Table for the Individual Effects of age (centered) and Processing Speed on Indicators of Shifting

		Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
Coefficients		B	Std. Error	Beta		
Local Global Accuracy						
	(Constant)	0.051	0.16		0.319	0.750
	Age	-0.027	0.009	-0.296	-2.917	**0.004**
	Speed	0	0	-0.072	-0.708	0.481
Local Global RT						
	(Constant)	441.858	208.406		2.12	0.037
	Age	-27.022	12.058	-0.224	-2.241	**0.028**
	Speed	-0.602	0.25	-0.241	-2.41	**0.018**
Number Letter Accuracy						
	(Constant)	0.039	0.166		0.235	0.815
	Age	-0.028	0.01	-0.306	-2.987	**0.004**
	Speed	-1.63	0	-0.008	-0.083	0.934
Number Letter RT						

(Constant)	321.892	192.233		1.674	0.098
Age	-20.143	11.058	-0.192	-1.821	0.072
Speed	-0.061	0.229	-0.028	-0.265	0.791

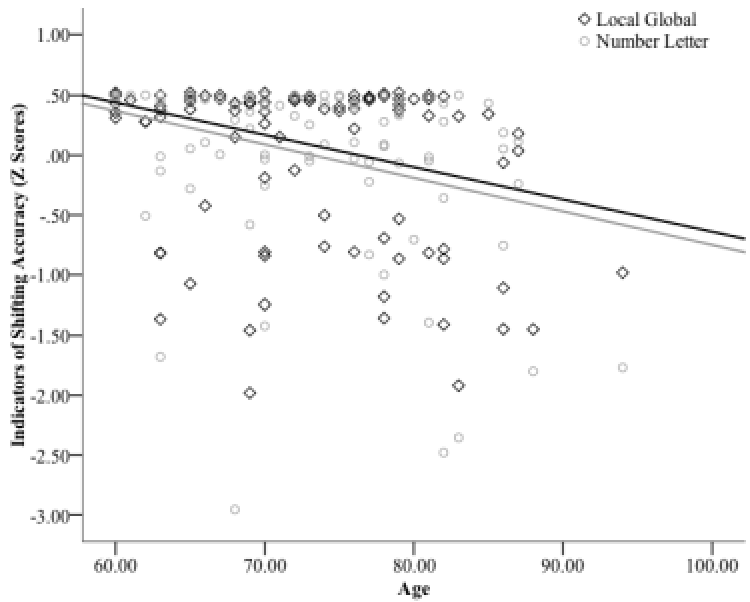

Figure 4. Scatterplot for the Effects of age on Indicators of Shifting Accuracy, After Controlling for Processing Speed.

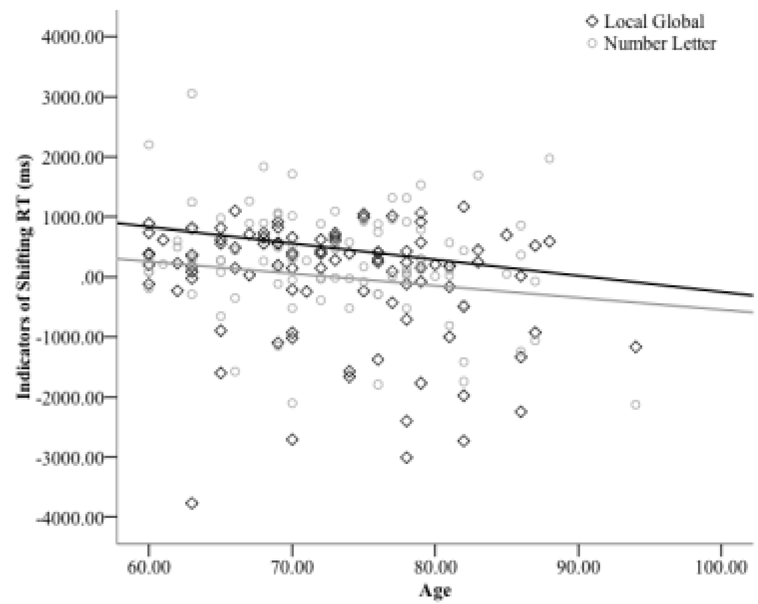

Figure 5. Scatterplot for the Effects of age on Indicators of Shifting RT, After Controlling for Processing Speed.

***Indicators of Updating*.** As can be seen in Table 5, together age and processing speed (combined) significantly predicted Keep Track RT, R^2 = .155, $F(2, 87) = 7.975$, $p < .005$, and Letter Memory RT, R^2 = .066, $F(2, 90) = 3.187$, $p < .05$. At the individual predictor level (see Table 6), age individually significantly predicted Keep Track accuracy, $b = -.027$, $t = -2.005$, $p < .05$, and RT, $b = 241.022$, $t = 3.968$, $p < .005$, and Letter Memory RT, $b = 49.982$, $t = 2.426$, $p < .05$. Processing speed did not individually significantly predict any of the Updating outcome variables. As predicted, *the processing speed theory* was not supported for Keep Track accuracy, Keep Track RT, Letter Memory accuracy, and Letter Memory RT.

Table 5

Regression Table for the Combined Effects of age (centered) and Processing Speed on Indicators of Updating

	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
Keep Track Accuracy	.230	0.053	0.031	0.971	0.053	2.43	2	87	0.094
Keep Track RT	.394	0.155	0.136	4381.689	0.155	7.975	2	87	**0.001**
Letter Memory Accuracy	.173	0.03	0.008	0.1	0.03	1.394	2	90	0.253
Letter Memory RT	.257	0.066	0.045	1538.816	0.066	3.187	2	90	**0.046**

Table 6

Regression Table for the Individual Effects of age (centered) and Processing Speed on Indicators of Updating

Coefficients		Unstandardized Coefficients: B	Unstandardized Coefficients: Std. Error	Standardized Coefficients: Beta	*t*	Sig.
Keep Track Accuracy						
	(Constant)	0.188	0.228		0.825	0.412
	Age	-0.027	0.013	-0.212	-2.005	**0.048**
	Speed	0	0	-0.064	-0.61	0.544
Keep Track RT						
	(Constant)	10137.212	1031.471		9.828	0.000
	Age	241.022	60.734	0.395	3.968	**0.000**
	Speed	-0.176	1.226	-0.014	-0.143	0.886
Letter Memory Accuracy						
	(Constant)	0.323	0.233		1.385	0.169
	Age	-0.011	0.013	-0.087	-0.83	0.409
	Speed	0	0	-0.139	-1.324	0.189
Letter Memory RT						

(Constant)	2586.481	359.298		7.199	0.000
Age	49.982	20.604	0.249	2.426	**0.017**
Speed	0.158	0.43	0.038	0.368	0.714

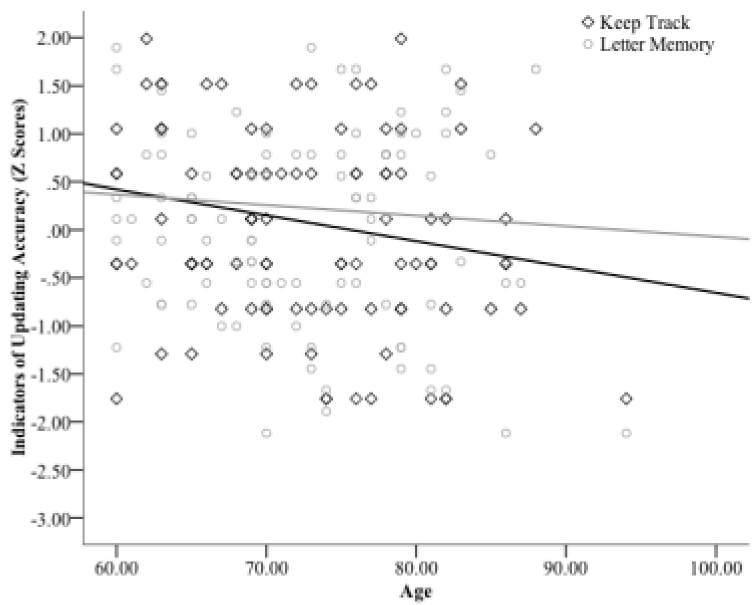

Figure 6. Scatterplot for the Effects of age on Indicators of Updating Accuracy, After Controlling for Processing Speed.

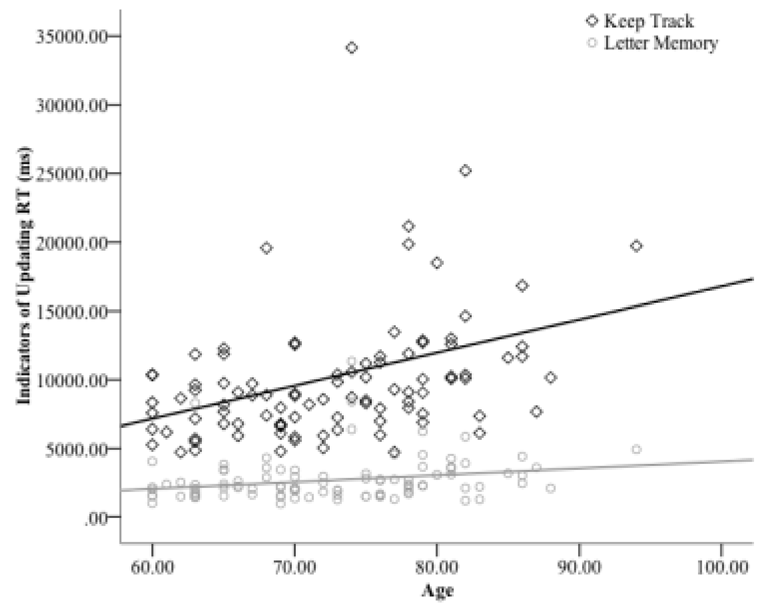

Figure 7. Scatterplot for the Effects of age on Indicators of Updating RT, After Controlling for Processing Speed.

Indicators of Inhibiting. As can be seen in Table 7, together age and processing speed (combined) significantly predicted Go/No Go RT, R^2 = .136, $F(2, 91) = 7.141$, $p < .005$, and Stop Signal RT, R^2 = .249, $F(2, 91) = 15.124$, $p < .005$. At the individual predictor level (see Table 8), age individually significantly predicted Stop Signal RT, $b = 9.066$, $t = 3.094$, $p < .005$. Processing speed individually significantly predicted Go/No Go RT, $b = .043$, $t = 3.247$, $p < .005$, and Stop Signal RT, $b = .222$, $t = 4.088$, $p < .005$. As predicted, *the processing speed theory* was not supported for Go/No Go accuracy, Stop Signal accuracy and Stop Signal RT. *The processing speed theory* was supported for Go/No Go RT, however; that is, processing speed significantly contributed to the regression model above and beyond the contributions of age for Go/No Go RT.

Overall, as predicted, *the processing speed theory* did not significantly contribute to the regression model above and beyond age for almost all executive outcome variables. It did however significantly contribute to the regression model above and beyond age for the RT variable of the Go/No Go task. This will be explored further in the discussion section.

Table 7

Regression Table for the Combined Effects of age (centered) and Processing Speed on Indicators of Inhibiting

					Change Statistics				
	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
Go/No Go Accuracy	.102	0.01	-0.011	0.399	0.01	0.48	2	91	0.620
Go/No Go RT	.368	0.136	0.117	47.972	0.136	7.141	2	91	**0.001**
Stop Signal Accuracy	.188	0.035	0.014	0.659	0.035	1.667	2	91	0.195
Stop Signal RT	.499	0.249	0.233	194.714	0.249	15.124	2	91	**0.000**

Table 8

Regression Table for the Individual Effects of age (centered) and Processing Speed on Indicators of Inhibiting

		Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
Coefficients		B	Std. Error	Beta		
Go/No Go Accuracy						
	(Constant)	0.183	0.093		1.973	0.052
	Age	-0.003	0.005	-0.063	-0.603	0.548
	Speed	-7.60E-05	0	-0.072	-0.684	0.496
Go/No Go RT						
	(Constant)	352.864	11.124		31.72	0.000
	Age	0.95	0.642	0.145	1.479	0.143
	Speed	0.043	0.013	0.319	3.247	**0.002**
Stop Signal Accuracy						
	(Constant)	0.2	0.153		1.307	0.194
	Age	-0.012	0.009	-0.137	-1.317	0.191
	Speed	0	0	-0.112	-1.076	0.285
Stop Signal RT						

(Constant)	694.937	45.153		15.391	0.000
Age	8.066	2.607	0.284	3.094	**0.003**
Speed	0.222	0.054	0.375	4.088	**0.000**

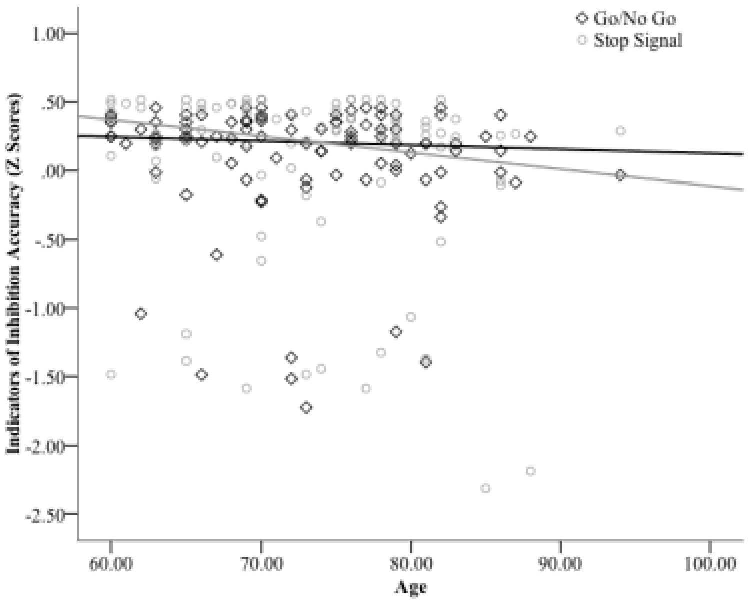

Figure 8. Scatterplot for the Effects of age on Indicators of Inhibiting Accuracy, After Controlling for Processing Speed.

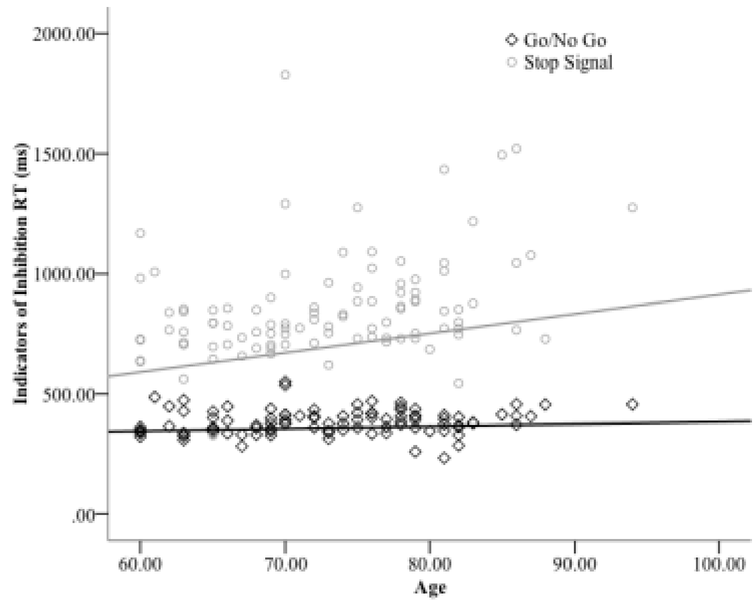

Figure 9. Scatterplot for the Effects of age on Indicators of Inhibiting RT, After Controlling for Processing Speed.

Inhibition deficit theory. The analyses outlined above were also utilized to assess *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988). Age was hypothesized to negatively affect scores on the four indicators of Inhibiting above and beyond other indicators of EFs.

As described above and seen in Tables 7 and 8 and Figures 8 and 9, looking at the four indicators of the two Inhibiting measures (i.e., the Go/No Go and Stop Signal tasks) revealed that age did not individually predict Go/No Go accuracy and RT, as well as Stop Signal accuracy. Age only individually significantly predicted Stop Signal RT (i.e., significantly slower Stop Signal RT with older age).

The majority (i.e., 3/4) of Inhibiting indicators were not individually significantly predicted by age. Also, as outlined in the previous section, age significantly contributed to many of the other EFs variables. Based on these results, indicators of Inhibiting were generally not affected by age above and beyond other EFs indicators; hence, *the inhibition deficit theory of cognitive aging* was not supported, which goes against our hypothesis. This will be explored further in the discussion section.

Dedifferentiation hypothesis. MANCOVA analyses were conducted to examine the relationships among the 13 indicators of EFs as a function of age, after controlling for processing speed. Interaction variables were created for each of the indicators (i.e., age by each individual indicator of EFs). It was hypothesized that *the dedifferentiation hypothesis* (Garrett, 1946) would not be supported by our analyses and that EFs would remain significantly differentiated with age.

Indicators of executive accuracy. As predicted, the hypothesis of dynamic dedifferentiation with old age (progressively increasing correlations amongst cognitive functions) was not supported for accuracy scores on the EFs tasks; that is, indicators of executive accuracy did not significantly correlate as a function of age. This suggests that indicators of accuracy for Shifting, Updating, and Inhibiting remain significantly diverse with age, after accounting for processing speed.

Indicators of executive RT. The hypothesis of dynamic dedifferentiation with old age was not supported for the majority of RT scores on the EFs tasks as well; that is, most indicators of executive RT did not significantly correlate as a function of age. As seen in Tables 9 and 10 below, two pairs of indicators of EFs RT did significantly correlate as a function of age however; that is, RTs for the Keep Track (Updating) and Number Letter (Shifting) tasks were significantly related similarly across ages, $b = -.011$, $t = -4.457$, $p < .005$, as well as RTs for the Letter Memory (Updating) and Number Letter (Shifting) tasks, $b = -.029$, $t = -2.983$, $p < .005$.

This suggests that indicators of RT for most tasks of Shifting, Updating, and Inhibiting remained significantly diverse with age, after accounting for processing speed. MANCOVA results revealed statistically significant larger correlations with increasing age among two pairs of executive RT indicators, which support *the dedifferentiation hypothesis* and goes against our predictions. This will be explored further in the discussion section.

Table 9

MANCOVA Table for the Interaction between Keep Track and Number Letter RT

DV	Parameter	B	Std. Error	t	Sig.
Number Letter RT	Intercept	218.81	257.708	0.849	0.398
	Keep Track RT	0.026	0.019	1.361	0.177
	Age (centered)	-15.686	11.238	-1.396	0.167
	Interaction Between age and Keep Track RT	-0.011	0.003	-4.457	**0.000**
	Speed	-0.042	0.209	-0.201	0.841

Table 10

MANCOVA Table for the Interaction between Letter Memory and Number Letter RT

DV	Parameter	B	Std. Error	t	Sig.
Number Letter RT	Intercept	353.584	235.511	1.501	0.137
	Letter Memory RT	0.009	0.056	0.161	0.873
	Age (centered)	-20.104	11.324	-1.775	0.080
	Interaction Between age and Letter Memory RT	-0.029	0.01	-2.983	**0.004**
	Speed	-0.013	0.221	-0.06	0.952

Evaluating the Moderating Role of QoL over Age-Related Differences in EFs

A multiple regression moderation analysis was conducted to examine the relationship between the 13 indicators of EFs, age, and the 11 QoL domains (i.e., four for the WHOQOL-BREF: physical health, psychological, social relationships and environment, and seven for the WHOQOL-OLD: sensory abilities, autonomy, past, present, and future activities, social participation, death and dying, intimacy, and one total score). Interaction variables were created for each of the 11 QoL domain scores (age by each individual QoL score). A *buffering interaction* (Cohen et al., 2003, 2013) was predicted, where QoL (moderator) would weaken the effects of age (IV) on EFs (DVs).

Indicators of global EFs. At the individual predictor level, only the sensory abilities domain individually significantly predicted the indicator of global EFs, $R^2 = .055$, $F(1, 94) = 5.484$, $p < .05$. The moderation interaction between age and sensory abilities was significant, $b = .001$, $t = 1.991$, $p < .05$, as well as the interaction between age and environment, $b = .001$, $t = 2.206$, $p < .05$. As predicted, these QoL domains were found to significantly moderate the effect of age on the indicator of global EFs, where higher scores on related scales were associated with higher scores on the indicator of global EFs (Figures 10-13 below). The effect of age on the indicator of global EFs utilized here thus appears to depend on the degree of QoL related to sensory abilities and environment.

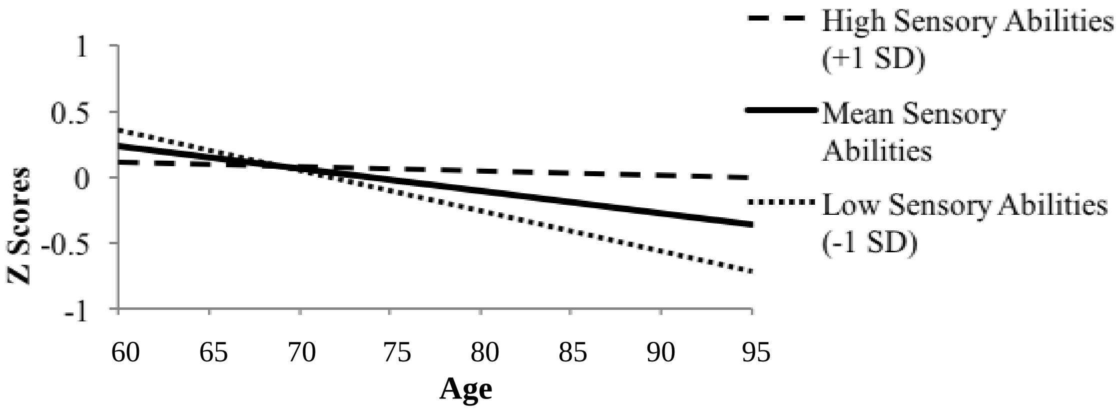

Figure 10. Moderation Interaction Between age, an Indicator of Global EFs, and Sensory Abilities.

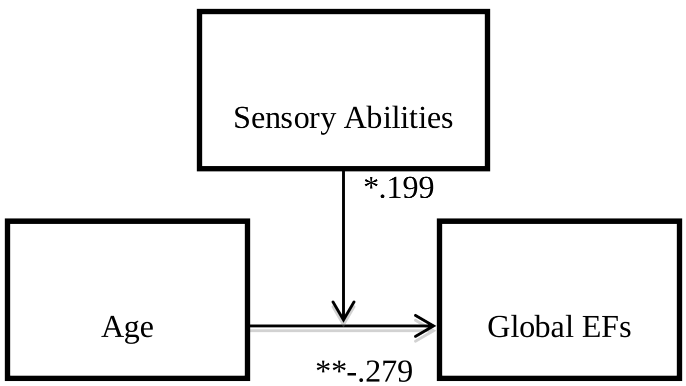

Figure 11. Diagram representing the moderation interaction between age, sensory abilities, and the indicator of global EFs. The moderating effect of sensory abilities over age-related differences in the indicator of global EFs was statistically significant (β = .199), as well as the individual relationship between age and the indicator of global EFs (β = -.279).

*$p < .05$, **$p < .01$

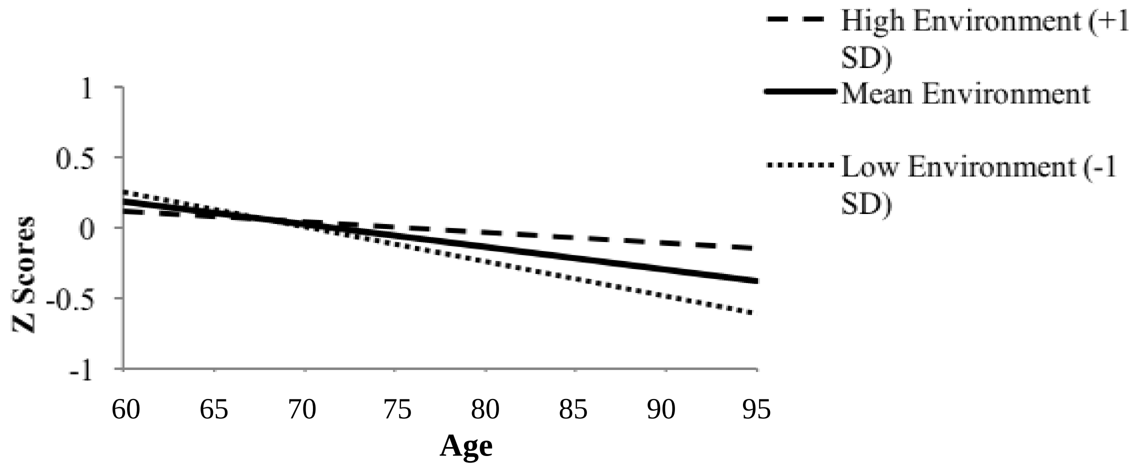

Figure 12. Moderation Interaction Between age, an Indicator of Global EFs, and Environment.

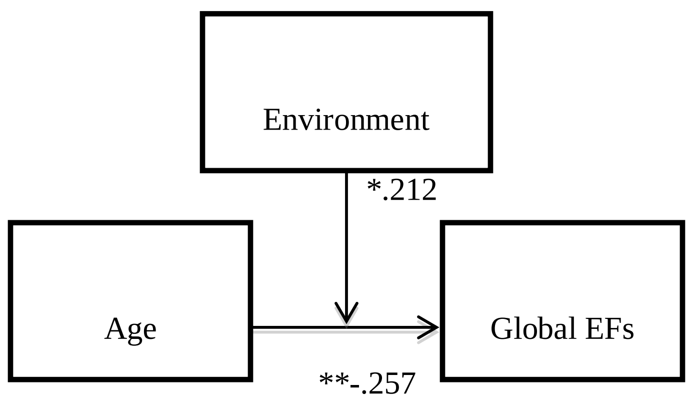

Figure 13. Diagram representing the moderation interaction between age, environment, and the indicator of global EFs. The moderating effect of the environment over age-related differences in the indicator of global EFs scores was statistically significant (β = .212), as well as the individual relationship between age and the indicator of global EFs (β = -.257).

*$p < .05$, ** $p < .01$

Indicators of Shifting. At the individual predictor level, only the sensory abilities domain individually significantly predicted indicators of Shifting for: Local Global accuracy: $R^2 = .068$, $F(1, 92) = 6.715$, $p < .05$, and RT: $R^2 = .108$, $F(1, 92) = 11.125$, $p < .005$, and Number Letter RT: $R^2 = .054$, $F(1, 89) = 5.090$, $p < .05$. The moderation interaction between age and the physical domain was bordering significance for Number Letter RT: $R^2 = .101$, $F(1, 92) = 3.449$, $p = .055$, and the interactions between age and environment for Number Letter RT: $R^2 = .112$, $F(1, 92) = 3.876$, $p < .05$, and age and social participation for Number Letter RT: $R^2 = .093$, $F(1, 88) = 3.023$, $p < .05$ were significant. As predicted, these QoL domains were found to significantly moderate the effect of age on these indicators of Shifting (see Figures 14-17 below). The effect of age on the aforementioned indicators of Shifting thus appears to depend on the degree of QoL related to environment, social participation, and potentially physical health.

Of note, higher scores on the aforesaid accuracy measures were associated with better performance on related Shifting tasks. Regarding results pertaining to indicators of RT, again, unlike other RT indicators, those utilized for the Local Global and Number Letter tasks were based on a ‘shift cost’ calculation. Similar to the results outlined in *the processing speed theory* section, the significant moderation interactions between age and QoL (for physical, environment, and social participation) with Number Letter RT suggested reduced ‘shift costs’ with age. More specifically, when the effects of age and QoL (for physical, environment, and social participation) over Number Letter RT were combined, a decrease in ‘shift costs’ was observed. As mentioned earlier, understanding ‘shift costs’ themselves is necessary to interpret these results. An explanation and relevant literature is included in the discussion section (see subsection on unexpected relationships).

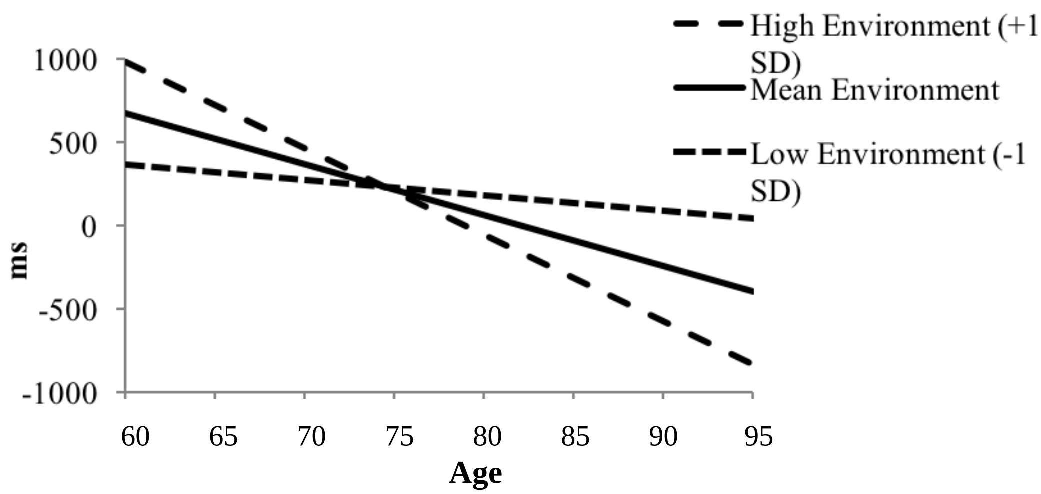

Figure 14. Moderation Interaction Between age, Number Letter RT, and Environment.

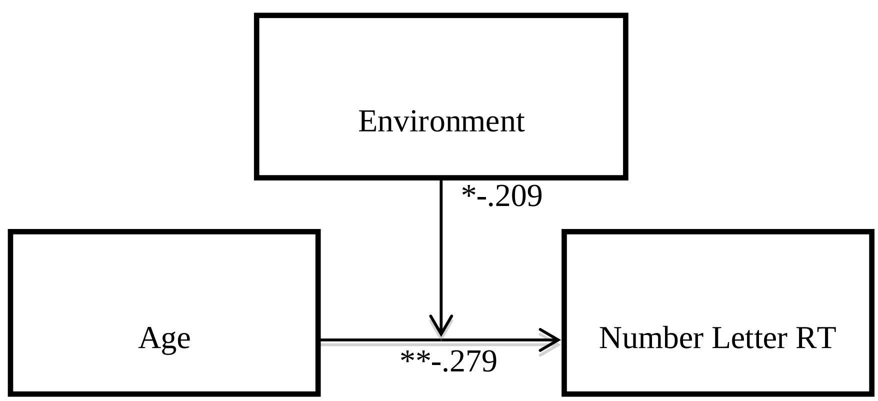

Figure 15. Diagram representing the moderation interaction between age, environment, and Number Letter RT. The moderating effect of the environment over age-related differences in Number Letter RT scores was statistically significant (β = -.209), as well as the individual relationship between age and Number Letter RT (β = -.279).

*$p < .05$, ** $p < .01$

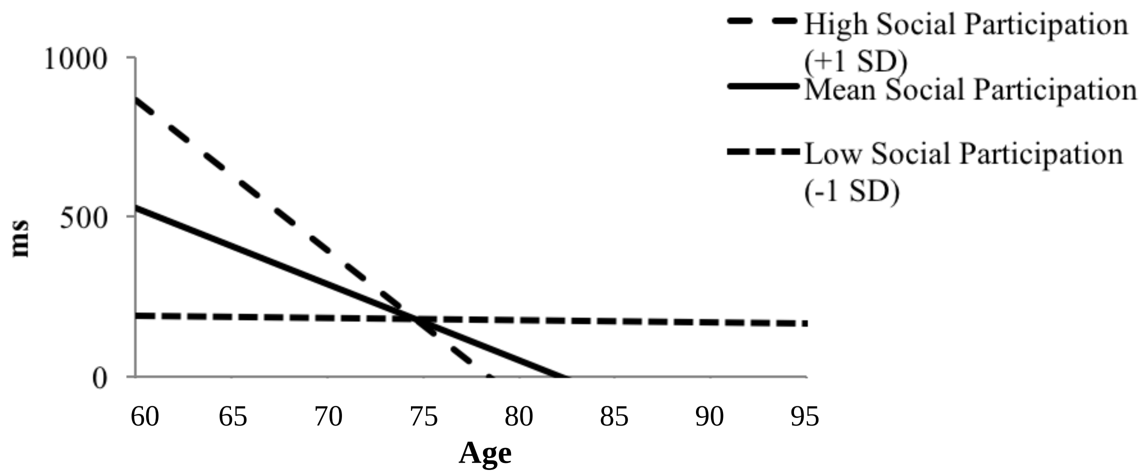

Figure 16. Moderation Interaction Between age, Number Letter RT, and Social Participation.

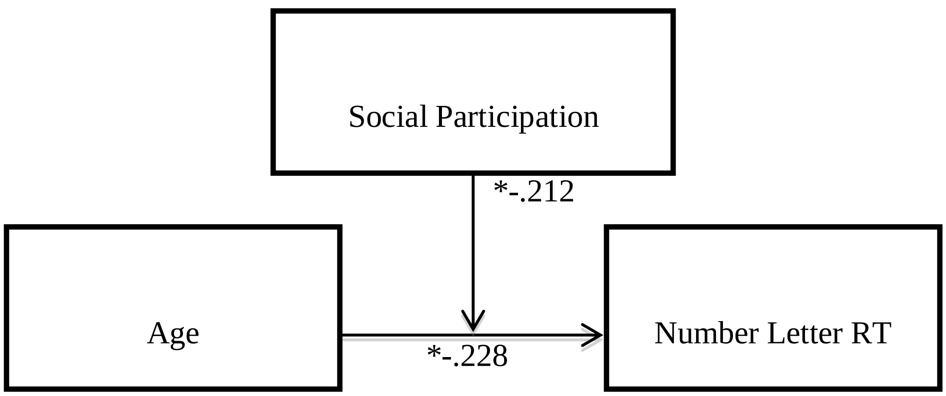

Figure 17. Diagram representing the moderation interaction between age, social participation, and Number Letter RT. The moderating effect of social participation over age-related differences in Number Letter RT scores was statistically significant (β = -.212), as well as the individual relationship between age and Number Letter RT (β = -.228).

*$p < .05$

***Indicators of Updating*.** At the individual predictor level, the following QoL domains individually significantly predicted indicators of Updating: psychological for Letter Memory accuracy: R2 = .040, *F*(1, 96) = 3.989, p < .05, sensory abilities for Keep Track accuracy: R2 = .046, F(1, 90) = 4.324, *p* < .05, and intimacy for Keep Track accuracy: R^2 = .047, *F*(1, 84) = 4.145, *p* < .05. The moderation interaction between age and social relationships was significant for Keep Track accuracy: R^2 = .106, *F*(1, 91) = 3.607, *p* < .05, as well as the interaction between age and environment for Letter Memory accuracy: R^2 = .064, *F*(1, 95) = 2.164, *p* < .05. As predicted, these QoL domains were found to significantly moderate the effect of age on these indicators of Updating, where higher scores on related scales were associated with better performance on related Updating tasks (see Figures 18-21 below). The effect of age on the aforementioned indicators of Updating thus appears to depend on the degree of QoL related to social relationships and environment.

Of note, as shown below, the direction of the relationship between age, social relationships, and Keep Track accuracy was unforeseen. More specifically, the results suggest that high social relationships' ratings were associated with greater age-related deficits in Keep Track accuracy. This goes against the hypothesized buffering effect of QoL on age-related executive differences. This effect will be discussed further in the later part of the discussion section (see subsection on unexpected relationships).

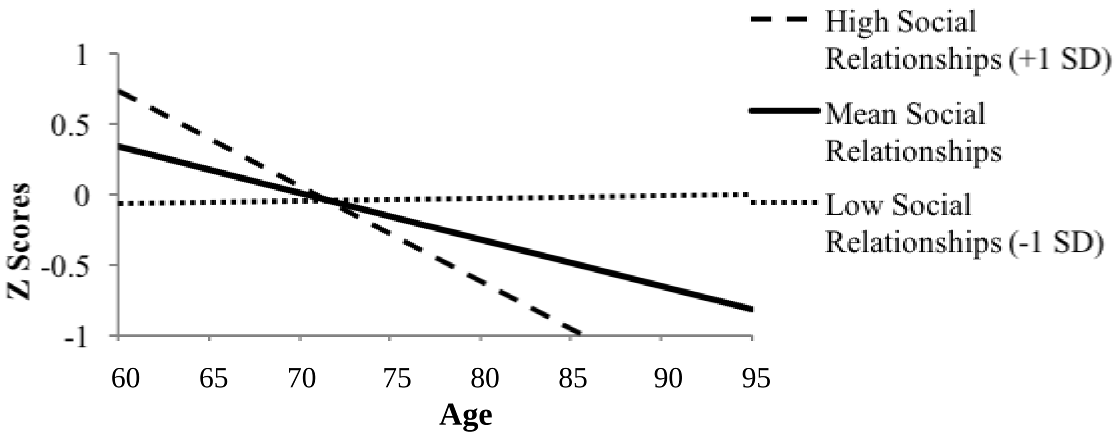

Figure 18. Moderation Interaction Between age, Keep Track Accuracy, and Social Relationships.

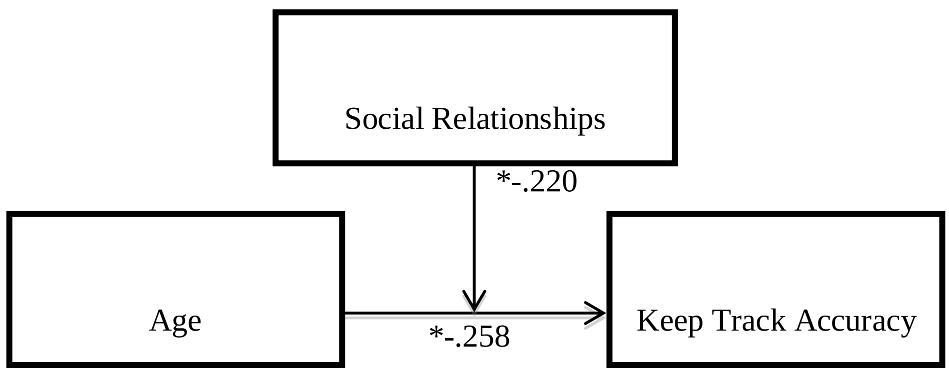

Figure 19. Diagram representing the moderation interaction between age, social relationships, and Keep Track accuracy. The moderating effect of social relationships over age-related differences in Keep Track accuracy scores was statistically significant (β = -.220), as well as the individual relationship between age and Keep Track accuracy (β = -.258).

*$p < .05$

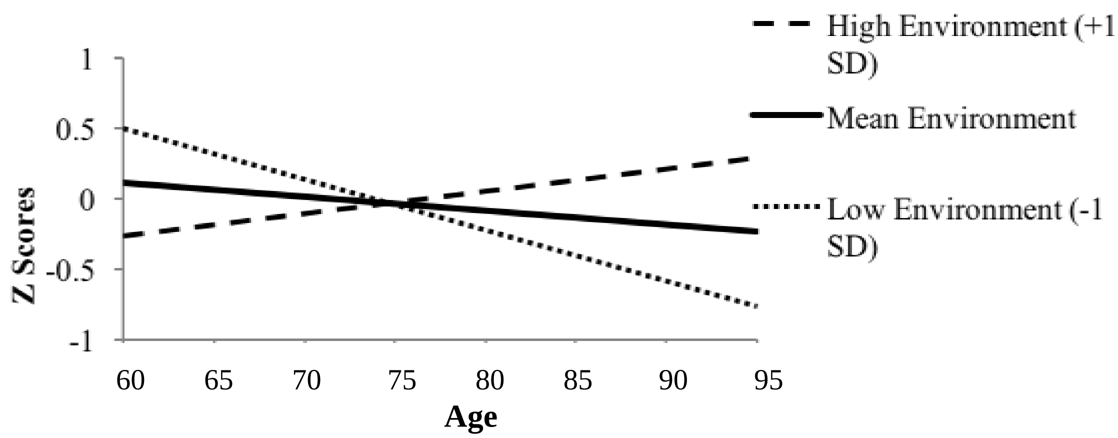

Figure 20. Moderation Interaction Between age, Letter Memory Accuracy, and Environment.

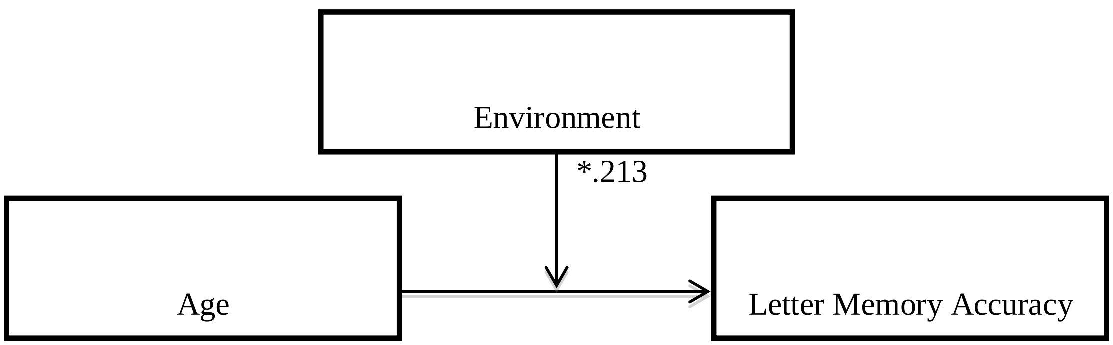

Figure 21. Diagram representing the moderation interaction between age, environment, and Letter Memory accuracy. The moderating effect of the environment over age-related differences in Letter Memory accuracy scores was statistically significant (β = .213). The individual relationship between age and Letter Memory accuracy was not significant in the moderation model (β = -.080).

*p < .05

Indicators of Inhibiting. At the individual predictor level, the following QoL domains individually significantly predicted indicators of Inhibiting: physical health for Go/No Go RT: R^2 = .069, $F(1, 98) = 7.248$, $p < .01$, environment for Stop Signal accuracy: R^2 = .049, $F(1, 95)$ = 4.855, $p < .05$, sensory abilities for Stop Signal accuracy: R^2 = .045, $F(1, 91) = 4.326$, $p < .05$, and RT: R^2 = .072, $F(1, 91) = 7.087$, $p < .01$, autonomy for Go/No Go accuracy: R^2 = .092, F(1, 94) = 9.475, $p < .005$, and past, present, and future activities for Go/No Go RT: R^2 = .053, F(1, 94) = 5.261, $p < .05$,. The moderation interaction between social relationships and age was bordering significance for Stop Signal accuracy: R^2 = .073, $F(1, 92) = 2.412$, $p = .053$; the moderation interaction with age was significant for the domains of environment for Stop Signal accuracy: R^2 = .140, $F(1, 93) = 5.057$, $p < .05$, autonomy for Go/No Go RT: R^2 = .090, $F(1, 92)$ = 3.031, $p < .05$, death and dying for Stop Signal accuracy: R^2 = .099, $F(1, 85) = 3.116$, $p < .05$, intimacy for Go/No Go accuracy: R^2 = .080, $F(1, 86) = 2.498$, $p < .05$, and total QoL for Go/No Go accuracy: R^2 = .121, $F(1, 80) = 3.663$, $p < .05$, it was also bordering significance for this last domain and Stop Signal accuracy: R^2 = .093, $F(1, 78) = 2.651$, $p = .056$. As predicted, these QoL domains were found to significantly moderate the effect of age on these indicators of Inhibiting, where higher scores on related scales were associated with better performance on related Inhibiting tasks (see Figures 22-30 below). The effect of age on the aforementioned indicators of Inhibiting thus appears to depend on the degree of QoL related to environment, autonomy, death and dying, intimacy, and total QoL, and potentially social relationships.

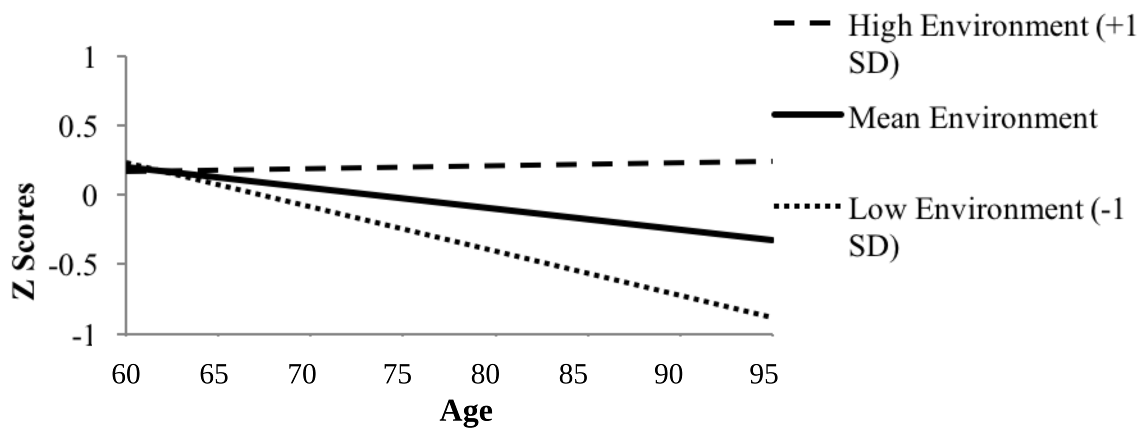

Figure 22. Moderation Interaction Between age, Stop Signal Accuracy, and Environment.

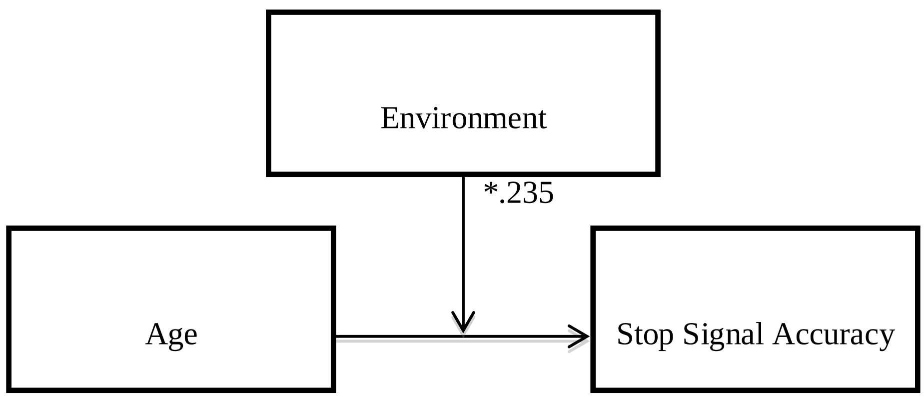

Figure 23. Diagram representing the moderation interaction between age, environment, and Stop Signal accuracy. The moderating effect of the environment over age-related differences in Stop Signal accuracy scores was statistically significant (β = .235). The individual relationship between age and Stop Signal accuracy was not significant in the moderation model (β = -.167).

*$p < .05$

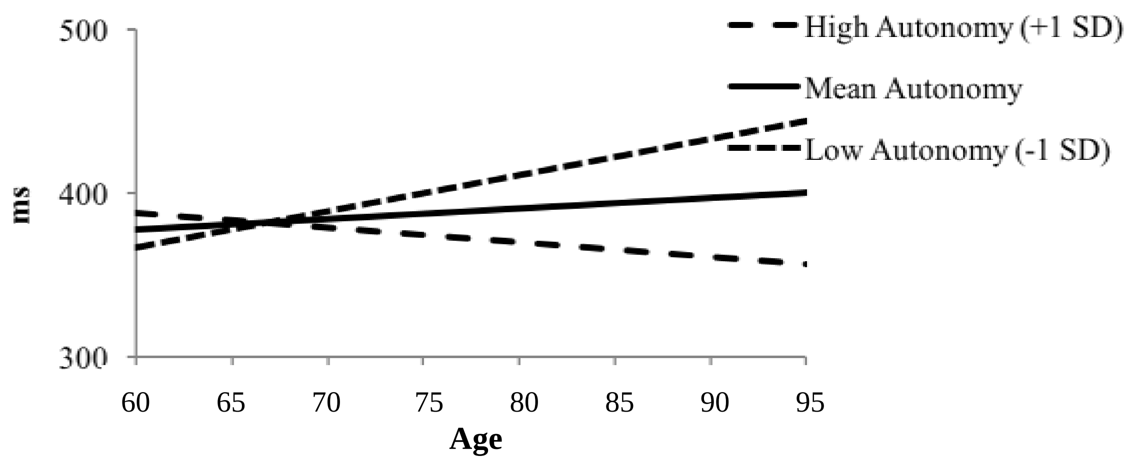

Figure 24. Moderation Interaction Between age, Go/No Go RT, and Autonomy.

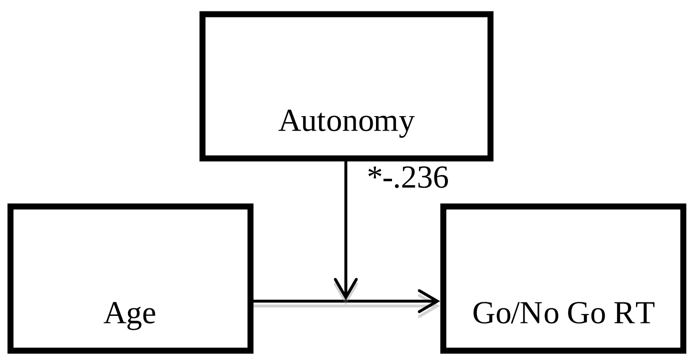

Figure 25. Diagram representing the moderation interaction between age, autonomy, and Go/No Go RT. The moderating effect of autonomy over age-related differences in Go/No Go RT scores was statistically significant ($\beta = -.236$). The individual relationship between age and Go/No Go RT was not significant in the moderation model (.102).

*$p < .05$

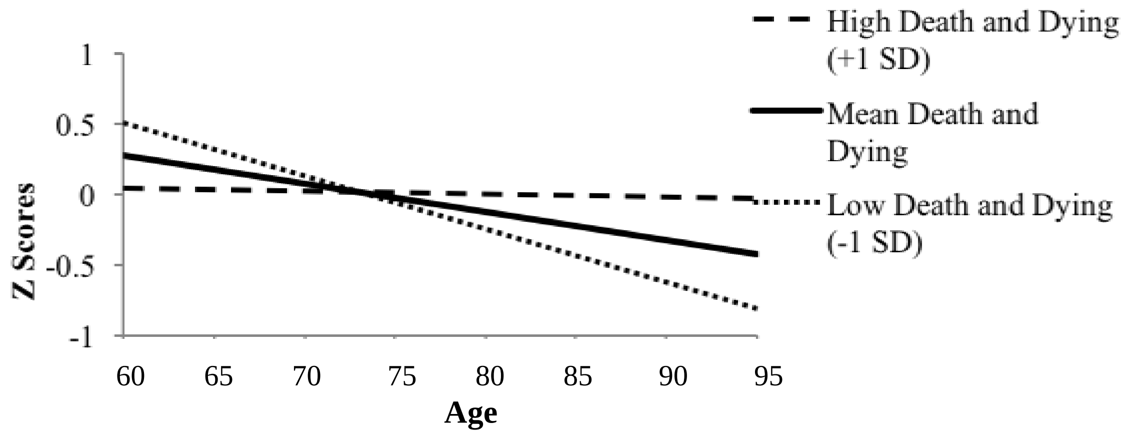

Figure 26. Moderation Interaction Between age, Death and Dying, and Stop Signal Accuracy.

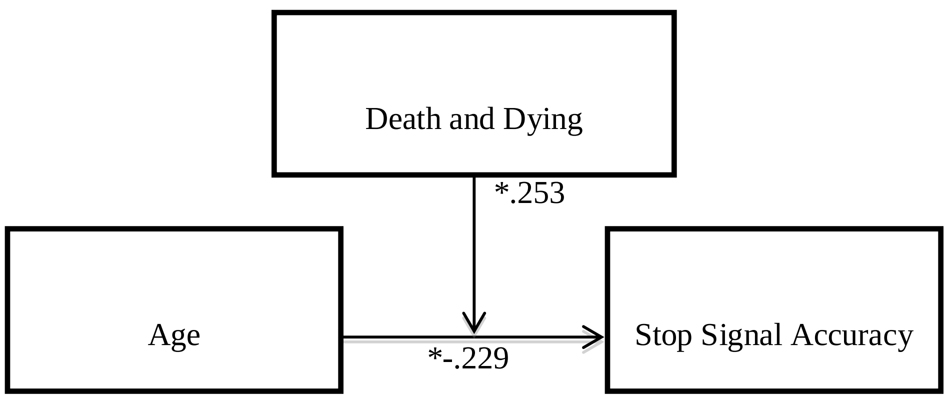

Figure 27. Diagram representing the moderation interaction between age, death and dying, and Stop Signal accuracy. The moderating effect of death and dying over age-related differences in Stop Signal accuracy scores was statistically significant (β = .253), as well as the individual relationship between age and Stop Signal accuracy (β = -.229).

$^*p < .05$

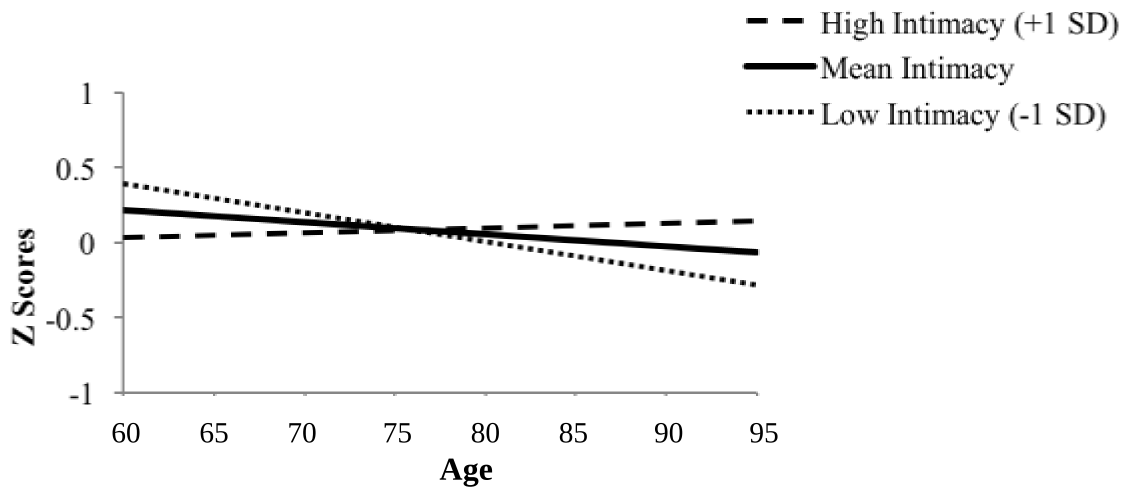

Figure 28. Moderation Interaction Between age, Intimacy, and Go/No Go Accuracy.

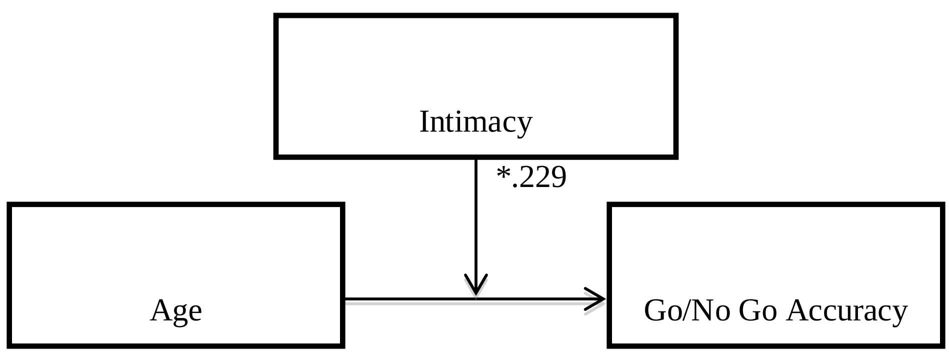

Figure 29. Diagram representing the moderation interaction between age, intimacy, and Go/No Go accuracy. The moderating effect of intimacy over age-related differences in Go/No Go accuracy scores was statistically significant (β = .229). The individual relationship between age and Go/No Go accuracy was not significant in the moderation model (β = -.151).

*$p < .05$

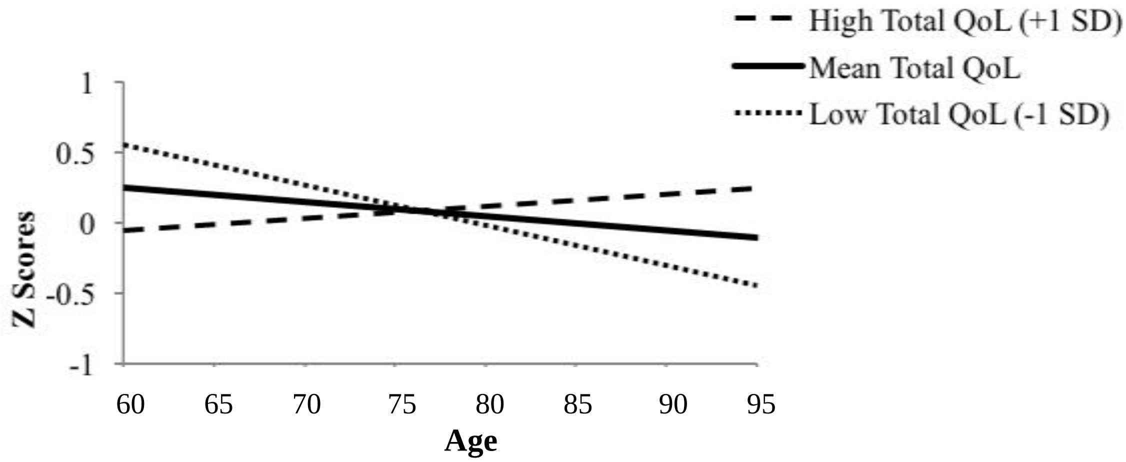

Figure 30. Moderation Interaction Between age, Total QoL, and Go/No Go Accuracy.

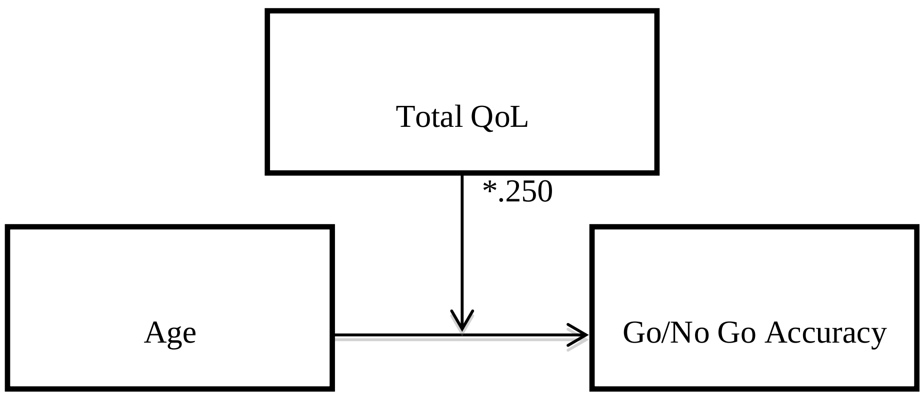

Figure 31. Diagram representing the moderation interaction between age, Total QoL, and Go/No Go accuracy. The moderating effect of total QoL over age-related differences in Go/No Go accuracy scores was statistically significant (β = .250). The individual relationship between age and Go/No Go accuracy was not significant in the moderation model (β = -.172).

*$p < .05$

Evaluating the Role of Education, Marital Status, Illness, and Gender over EFs and QoL

MANCOVA analyses were conducted to examine the relationships among EFs, processing speed, QoL and the following demographic variables: education, marital status, illness (participants reported if they currently suffer from an illness that they believe significant impacts their life), and gender.

Covariates of EFs.

Education. EFs accuracy and RT scores were not significantly associated with participants' level of education. Processing speed, however, was significantly associated with education, where faster processing speed was related to higher education status, $b = -332.036$, $t = -2.376$, $p < .05$. It should be noted that most participants reported having tertiary education levels (i.e., 89.2%; see Table 1).

Marital status. EFs accuracy and RT scores were not significantly associated with participants' marital status.

Illness. EFs accuracy and RT scores were not significantly associated with illness.

Gender. The majority of EFs accuracy and RT scores were not significantly associated with participants' gender. The following variables were found to be significantly associated with gender: the indicator of global EFs (women performed significantly better than men), $b = .245$, $t = 2.932$, $p < .005$, Letter Memory accuracy (women performed significantly better than men), $b = .607$, $t = 2.652$, $p = .01$, Local Global RT (men performed significantly better/faster than women), $b = 506.509$, $t = 2.462$, $p < .05$, and Go/No Go RT (men performed significantly better/faster than women), $b = 32.169$, $t = 2.817$, $p < .01$.

Covariates of QoL.

***Education*.** Only the following WHOQOL-OLD facets were found to be associated with education: death and dying was significant, $b = 16.184$, $t = 2.377$, $p < .05$, while sensory abilities was bordering significance, $b = 9.949$, $t = 1.964$, $p = .053$, where higher values were related to higher education status.

***Marital status*.** The majority of QoL domains were not significantly associated with participants' marital status. The following WHOQOL-OLD facet was found to be significantly associated with marital status: intimacy, $b = -4.208$, $t = -2.423$, $p < .05$, where participants who reported being married or living as married endorsed significantly higher intimacy values than participants who reported being divorced or widowed.

***Illness*.** The majority of QoL domains were not significantly associated with illness. The following were found to be significantly associated with illness: the WHOQOL-BREF domains of physical health, $b = -11.653$, $t = -2.388$, $p < .05$, and social relationships, $b = -19.998$, $t = -2.700$, $p < .01$, and the WHOQOL-OLD facets of past, present, and future activities, death and dying, intimacy, and total QoL, where participants who reported having a major illness endorsed significantly lower values on related scales than participants who reported no major illness.

***Gender*.** The majority of QoL domains were not significantly associated with gender. The following were found to be significantly associated with gender: the WHOQOL-BREF psychological domain (men endorsed significantly higher values than women), $b = -5.599$, $t = -2.605$, $p < .05$, and the WHOQOL-OLD intimacy facet (men endorsed significantly higher values than women), $b = -10.794$, $t = -2.275$, $p < .05$.

Overall, a few associations between QoL domains and executive indicators were revealed by the analyses. Although a cohesive pattern did not appear to exist, these findings may help explain some of the individual differences in EFs and QoL in older adulthood. The aforementioned significant relationships will be addressed in the discussion section.

Discussion

Examining Age-Related Differences in EFs and the Contribution of EFs Theories

Processing speed theory. Correlation and hierarchical multiple regression analyses examining the relationship between indicators of EFs, age and processing speed showed that age and processing speed (combined) significantly contributed to performance for most executive variables. At the individual predictor level, as hypothesized, age individually significantly predicted the majority of EFs indicators. Conversely, processing speed only individually significantly predicted three of the executive indicators (i.e., one indicator of Shifting: Local Global RT, and two indicators of Inhibiting: Go/No Go and Stop Signal RT).

Of note, all of the aforementioned variables that were individually significantly associated with processing speed were related to task RT. Not surprisingly, two of these indicators, the Go/No Go and Stop Signal RTs, were extracted from the same tasks from which the processing speed scores were calculated. As explained previously, processing speed scores were obtained from averaging RTs on the first blocks of the Go/No Go and Stop Signal tasks. The first block of these tasks is meant to foster the development of a prepotent response and is not thought to involve executive abilities. It seems reasonable that non-executive (i.e., labeled here as processing speed) and executive (i.e., labeled here as RT) speed for these tasks would be significantly related. It is possible that the contributions of processing speed were not statistically significant for most the EFs tasks for this reason. Certainly, how processing speed is measured may impact whether it is found to significantly contribute to performance on complex cognitive tasks or not. As noted by Salthouse, "some measures [of processing speed] may not exhibit age-related slowing because it is not assumed that every measure scaled in units of time is affected by common or general influence(s) […and…] not all speed measures are postulated to be influenced by the hypothesized common speed factor(s)" such as age (p.415, 1996). Nonetheless, processing speed is generally indexed from non-executive blocks in a manner comparable to the present estimate. Adrover-Roig and colleagues (2012) for instance used a "median RT of the pure blocks of the Stroop Word task, TMT-A and Digit Symbol" (p.290), and Albinet and colleagues (2012) used a simple RT measure where "[p]articipants had to respond to an auditory stimulus (a 100 ms, 2000-Hz tone) by pressing as quickly as possible a pre-defined key with their right thumb" (p.3). Hence, all in all, the current approach seems to be in line with the rest of the relevant literature.

Moreover, as hypothesized, *the processing speed theory* did not significantly contribute to the regression model above and beyond age for almost all executive-related performance differences, with the exception of the Go/No Go RT. Interestingly, the Go/No Go task was used to represent the Inhibiting component, which was predicted to show negative age-effects above and beyond other EFs. As it will be described further in the next section, *the inhibition deficit theory of cognitive aging* was not supported by our analyses. It is somewhat remarkable however that *the processing speed theory* only held true for one executive indicator and that this indicator was meant to represent the allegedly most age-sensitive cognitive function (i.e., Inhibiting, e.g., Hasher and Zacks, 1988).

Overall, congruent with the first goal and hypothesis for the present study, older age was found to be significantly associated with lower performance on the majority of EFs tasks, above and beyond the contributions of processing speed. That is, *the processing speed theory* (Salthouse, 1996) was not supported by our results, indicating that cognitive aging was not significantly associated with one global mechanism of slowed processing speed in this study. Again, the only exception to this was found for the Go/No Go task RT; it was noted above that the indicator used for processing speed might be a confounding factor in failing to reject *the processing speed theory* for this variable. It should be said that while age differences in processing speed were not sufficient to explain all age-related differences in EFs, processing speed did contribute to some EFs indicators, as mentioned previously. Hence, although the degree to which processing speed influences complex cognition is still debatable, the fact that it does contribute to some processes involved in cognitive aging is not.

Additionally, it should be noted that our results pertaining to *the processing speed theory* generally differed from those recently noted by Albinet and colleagues (2012). As mentioned earlier, their work inspired the theory-based methodological framework for our investigations. On one hand, analogous to the present endeavor, these authors had investigated performance difference in EFs, tapping onto Miyake's constructs (i.e., Shifting, Updating, and Inhibiting) while simultaneously accounting for processing speed. Their analyses had shown that EFs and processing speed shared mutual variance while simultaneously being independently affected by aging, which is comparable to our findings. More importantly however, their study also revealed that most of the variance in executive performance was shared somewhat evenly between age and processing speed. Their sample was constituted of younger (18-32 years) and older (65-80) healthy adults, which is perhaps why this effect was found. This type of approach is certainly common. It is indeed possible that *the processing speed theory* can only be supported when such comparisons are made, as opposed to examining the contributions of age on a continuum specifically targeting older adults. It may be that processing speed is one of the main contributors of executive age differences between healthy college students and older adults, whereas showing smaller effects when looking across the older adult lifespan (e.g., after the age of 60). Further studies looking at the validity of this theory throughout older adulthood would be helpful for clarification.

Inhibition deficit theory. As part of the analyses above, a secondary focus was placed on the specific relationship between age and indicators of Inhibiting (i.e., *the inhibition deficit theory of cognitive aging*, Hasher & Zacks, 1988). Most Inhibiting outcome variables (i.e., Go/No Go accuracy and RT, and Stop Signal accuracy) were not individually significantly predicted by age after accounting for speed. Conversely, age was found to individually significantly contribute to the indicator of global EFs and most of the indicators for Shifting and Updating. Against our predictions, these findings did not support *the inhibition deficit theory of cognitive aging*.

The hypothesis that our analyses would support this theory was based on empirical evidence in the relevant literature. Bell and colleagues (2008) for instance evaluated the theory with younger (*M* □= 23.68, SD = 3.06) and older (*M* = 67.94, SD = 6.87) adults and found that older age was associated with a significantly greater number of inhibitory errors. More recently, others (Rodríguez-Villagra et al. 2013) found results comparable to the last on a Go/No Go task for older participants (*M* = 73, SD = 2.63) compared to younger participants (*M* = 23, SD = 2.01). Similarly, another study (Crevier-Quintin, 2013) contrasting five tasks of EFs in younger (ages 30-40), middle-aged (50-60), and older adults (70 and older) revealed statistically significant poorer performance in older adults on two EFs tasks, one of which was the Go/No Go. What may have diminished the likelihood of finding analogous results in the current study is that once again, most research looking at aging-effects for Inhibiting typically compare younger and older adults. As noted for the previous executive theory, it is possible that such effects are more likely to be found when comparing these groups versus restricting the focus on older adults. At any rate, comparing EFs performance across the older adult lifespan here did shed light on the sensitivity of some Inhibiting indicators to confounding variables (i.e., speed and QoL). As noted throughout this dissertation, investigating the moderating role of particular external factors (i.e., 11 QoL domains) over executive age-effects was central to this study and will be discussed soon. Continuing to explore the impact of multifaceted internal and external influences over Inhibiting would be helpful to further clarify the unique age-related sensitivity of this executive component.

Few researchers have evaluated the combined impact of both internal and external factors over EFs. Despite the discrepancies described above, our results correspond with one of the only studies that have examined both *the processing speed theory* and *the inhibition deficit theory of cognitive aging* in relation to complex cognitive tasks. Specifically, Rush and colleagues (2006) found that after controlling for processing speed, age effects were present for some cognitive tasks, including small effects related to RT on the Stop Signal task (our study also only found inhibitory age effects for Stop Signal RT). Conversely, they found no effect on other tasks including the Go/No Go, leaving them unable to support *the inhibition deficit theory of cognitive aging*. The specific vulnerability of the Stop-Signal task to age-related differences will be discussed soon (see paragraph below regarding the "expanded inhibitory deficit theory" by Dennis & Cabeza, 2008). Moreover, Rush and colleagues (2006) suggested looking at correlations among various cognitive tasks as a potential explanation for these results and to investigate the potential uniformity of Inhibiting in older age. Considering correlations among EFs as a function of age represented a major goal for the current study and will be discussed in *the dedifferentiation hypothesis* section.

In keeping with the suggestion above, distinguishing the construct of Inhibiting from other EFs in healthy older adults has been said to represent an important challenge in this field (see Adrover-Roig, 2012). Hypothetically, the presence of high correlations across EFs tasks could underline issues of task impurity and/or poor discriminant validity (Burgess, 1997). Looking at correlations for indicators of Inhibiting in our study showed that for the Go/No Go, task accuracy was only significantly correlated with global EFs ($p < .05$), and task RT was only significantly correlated with Stop Signal RT ($p < .01$). This does not seem to indicate major issues with task impurity and discriminant validity. Some level of correlation across executive indicators is to be expected (e.g., Miyake et al., 2000). On the other hand, for the Stop Signal task, accuracy was significantly correlated with multiple EFs indicators: global EFs ($p < .01$), Local Global RT, and Keep Track accuracy ($p < .05$). This effect was similarly noted for the Stop Signal RT, which was significantly correlated with Letter Memory accuracy and RT ($p < .05$), Keep Track RT ($p < .05$), and Go/No Go RT as noted before. Miyake and colleagues (2000) purported that EFs were best represented by a three-factor model with clearly correlated yet distinct components that uniquely contribute to performance on complex executive tasks. Unlike them, our study did not focus on the theoretical development of a model of EFs and did not utilize latent variable and confirmatory factor analyses, which are ideal to explore the unity and diversity aspects of EFs. Nonetheless, our findings suggest that performance on some tasks might be more closely related than others, which for some variables (i.e., inter-correlations among RT variables), is not surprising. An exhaustive investigation of the unity and diversity aspects of EFs is beyond the scope of this dissertation; rather, the focus here was placed on age differences and the moderating role of QoL. Exploring these components, the correlations among EFs, as well as the contributions of such correlations to an empirical model of EFs represents a valuable future endeavor. Applying analytic approaches like those used by Miyake and colleagues represents an advantageous alternative for future investigations.

Again, the findings herein did no confirm the inhibitory hypothesis. According to some, this may be due to the tasks used to assess this construct. Specifically, some have suggested that age differences in Inhibiting are more easily detected via neuroimaging approaches compared to behavioral measures. Namely, a recent review of the literature on Inhibiting and cognitive aging (Lustig & Jantz, 2015) points to the importance of neural compensatory mechanisms relevant to inhibitory task performance. More specifically, it was said that the cost of top-down (i.e., executive) control used to compensate for failures in bottom-up processing (i.e., non-executive) is where most of the significant differences in performance lay. Hence, differences are said to be more obvious at the neural level (i.e., brain activity) as opposed to the behavioral level (e.g., response accuracy and RT scores). The latter suggests that even when significant performance differences between younger and older adults cannot be found behaviorally on Inhibiting tasks, brain imaging may indicate differential and/or impaired processing. This is called the “expanded inhibitory deficit theory” (Dennis & Cabeza, 2008), where “[c]ompared to young adults, older adults may show decreased activation in regions associated with inhibitory control […] but increased activity in regions that are the targets of that control […]" (Lustig & Jantz, 2015, p.62). Of relevance here, some have specifically suggested that the Stop-Signal task is more closely related to motor responses and more likely to elicit behavioral age effects, as opposed to the Go/No Go which is supposedly more “sensory-stimulus” related and not as likely to show such differential behavioral responses (Sebastian et al., 2013). It is thus possible that despite statistical evidence of major inhibitory age effects in the current study, there may still have been some undetected neural costs associated with performance and older age. As indicated in the introduction section, a comprehensive account of EFs including both neural and behavioral measures would be ideal. This approach could have allowed us to explore another important theory, *the prefrontal-executive theory* (West, 1996). Neuroimaging resources were not available for this study however. Nonetheless, one step that was taken to account for some aspects of differential neural compensation was counter-balancing the administration order of the EFs tasks to minimize fatigue effects. All in all, considering alternative tasks and a closer review of behaviorally-sensitive (vs. "sensory-stimulus" related) Inhibiting tasks may be helpful for future evaluations of the original and expanded *inhibition deficit theory of cognitive aging*.

Dedifferentiation hypothesis. As hypothesized, MANCOVA analyses examining the relationships among indicators of EFs as a function of age after controlling for processing speed did not support *the dedifferentiation hypothesis* (Garrett, 1946) for all of the executive accuracy measures and the global EFs indicator. This was also the case for almost all of the executive RT measures. However, two pairs of RT measures, a) the Keep Track and Number Letter tasks, and b) the Letter Memory and Number Letter tasks, did prove to be significantly more united as a function of age. These last results contradicted our predictions that *the dedifferentiation hypothesis* would not be supported for any of the EFs variables.

In the absence of an evident explanation, it is possible to consider potential reasons for this association based on the available literature. An element that may guide this query is that each pair of measures for which *the dedifferentiation hypothesis* held true contained one indicator for Updating and one for Shifting. This seems to align with empirical lines of enquiries pertaining to the organization of EFs. Hedden and Yoon (2006), for instance, employed structural equation modeling with a sample of 122 healthy older adults aged 63-82 to explore the structure of the same EFs as those utilized here. This study showed that a two-factor model best described these functions; namely, Inhibiting represented one factor, whereas Shifting and

Updating were best regarded as a unified process. This was in opposition to a three-factor model with each EFs representing a unique factor. These findings suggest the dedifferentiation of the Shifting and Updating constructs in this older adult sample, similarly to what was noted in our analyses for two pairs of executive measures. These results are different from those found by Miyake and colleagues (2000), which supported three distinct and intercorrelated factors in college students. Hedden and Yoon attributed this effect to their sample, which was restricted to older adults. Unlike most dedifferentiation research, their study did not include younger participants. As argued earlier, this seems to represent a more sensitive approach to evaluating theories circumscribed to cognition around the older adult lifespan; that is, some age-effects specific to older adulthood may be more easily exposed when comparisons are drawn among older adults themselves, versus younger and older participants.

In keeping with this and as mentioned in the introduction, various lines of inquiries from the Victoria Longitudinal Study served to explore EFs aging-effects in different cognitive status groups (i.e., cognitively elite, cognitively normal, and cognitively impaired). One of these analyses (de Frias, Dixon, & Strauss, 2009) suggested that EFs only remained significantly distinct or dedifferentiated in their group of cognitively elite older adults, while a one-factor solution more adequately represented the other groups. Evidence of the homogeneity of EFs in specific subgroups of older adults implies diverging aging processes based on cognitive status. Considering cognitive status represents an interesting approach to better understanding differences in performance and correlations among executive tasks. The majority of the current sample was comprised of individuals possessing a tertiary education level. Hence, the current study only looked at EFs differences in a relatively cognitively-homogeneous group, which perhaps confounded the results. Including a sample with greater demographic variability represents a crucial goal for future research.

Alternatively, to better understand these findings, one may consider similarities between the two pairs of RT measures that supported *the dedifferentiation hypothesis*. Again, the affected pairs of executive measures were a) the Keep Track and Number Letter tasks, and b) the Letter Memory and Number Letter tasks. Regarding the first pair, they both require keeping track of multiple types of stimuli (i.e., Keep Track: three to four stimulus categories; Number Letter: numbers and letters and screen location-based responses). As for the second pair, they both require keeping track of verbal stimuli (letters) that change constantly and must be cognitively updated accordingly. As stated earlier, deliberately directing one's attention to relevant stimuli, involving some level of planning and anticipation, is thought to be better in older children and young adults, than in young children and older adults (Diamond, 2013). The aforementioned Updating and Shifting tasks fall under the overarching umbrella of attention control. One requires that participants constantly redirect their attention to new stimuli (Updating) while the other controls where the focus of attention is placed (Shifting). In any case, the results herein suggest that significantly larger correlations with increasing age were found for only two pairs of executive RT indicators, which may reflect task demand resemblances.

Overall, as predicted, the present findings generally did not support *the dedifferentiation hypothesis* (Garrett, 1946), suggesting the preservation of diversity in EFs with older age. It was noted however that the relative homogeneity of our participants with regards to education likely contributed to the results. A more heterogeneous and specific account of demographic factors, similar to what was done by de Frias and colleagues (2009) would benefit future research on the relation among EFs with older age.

Examining the Moderating Role of QoL over Age-Related Differences in EFs

A multiple regression moderation analysis was conducted to examine a *buffering interaction* (Cohen et al., 2003, 2013) where QoL was predicted to weaken the negative effects of age on indicators of EFs. As hypothesized, the significant moderation relationships among age, indicators of QoL and EFs were found to be multifaceted. Also, considering the role of QoL over age-related differences in EFs represented the overarching goal of this research. Hence, careful consideration of these results follows.

The prevalent influence of environmental factors over EFs. As outlined in the results section, most of the significant QoL moderators were generally associated with one or two EFs indicators. There was one exception to this however. The WHOQOL-BREF environment domain was found to significantly moderate four indicators (i.e., global EFs indicator, Number Letter RT [Shifting indicator], Letter Memory accuracy [Updating indicator], and Stop Signal accuracy [Inhibiting indicator]). More importantly, it was the only QoL domain to be significantly related to indicators pertaining to all three EFs components and global EFs. In this context, environment was related to living circumstances and access to services (e.g., financial resources, freedom, physical safety and security, accessibility and quality to health and social care, participation in and opportunities for engagement in recreational and leisure activities). Environmental factors associated with QoL were indeed found to significantly moderate the deleterious effects of age on four executive indicators, impacting measures of both speed and accuracy (i.e., RT and accuracy variables).

The connection between aging, preserved and/or enhanced QoL, and external variables such as desirability of living situation, few barriers to physical activities in one's environment, and financial resources were discussed in the introduction (e.g., Bowling et al., 2002; Richard et al., 2004). Accessibility to such resources is known to be a valuable factor to physical health in older adults (e.g., Czaja, 2016; Solway, Estes, Goldberg, & Berry, 2010; Thorpe, Thorpe, Kennelty, & Pandhi, 2011). It seems reasonable that these factors might in turn affect the degree of cognitive differences in older age. In their recent review of geographical and physical environmental influences on cognitive aging, Cassarino and Setti (2015) argued that "the geographical environment - defined in terms of rurality vs. urbanisation, presence of green, environmental layout and complexity, levels of traffic and noise - can act as a source of brain training and possibly contribute to cognitive resilience in older age" (p.168). This is certainly in line with our findings. Similar to what was argued earlier in this dissertation, these authors outlined the importance of understanding multifaceted environmental factors. This could help significantly advance the development of strategies aimed at maintaining optimal/or improving cognitive functions in older adulthood.

Closely related to environmental factors, socioeconomic status was also discussed as an important mediator of cognitive aging in the cited review, which is in line with the present definition of environmental QoL. Another study cited earlier, the seminal English Longitudinal Study of Ageing (ELSA), also discussed wealth (i.e., socioeconomic status) as a covariate of well-being and cognitive decline in older adults (Allerhand, Gale, & Deary, 2014). The ELSA definition of wealth included savings and investments, value of any property or business assets, debt, and excluded pension assets. In over 10 000 individuals aged 50 to 90 years, where cognitive function and positive well-being were assessed four times over a six-year period, both cognitive function and well-being were found to start declining at age 70. More importantly and relevant to this study, most of the variation in cognition was explained by age, higher levels of well-being were associated with greater wealth and fewer problems with ADLs, and higher levels of cognition were associated with greater wealth. All in all, socioeconomic factors are undeniably related to crucial environmental components such as accessibility to resources. The present study and ELSA showed that they might be related to cognitive aging as well, which shows potential for intervention development.

The current findings regarding the powerful influences of environmental factors over satisfaction and cognition in older adults appear to be consistent with similar studies. Literature specifically focusing on the association between EFs, aging, and environmental factors is scarce however, hence the relevance of our study. Based on what was outlined herein, there seems to be some support and potential for the continued development of prevention and intervention endeavors over cognition and well-being in older adulthood.

Susceptibility of indicators of Inhibiting to QoL influences. Reviewing the moderation results not only revealed that one particular QoL domain (i.e., environment) had the most widespread influence over EFs variables but also, that indicators related to one executive component were considerably more susceptible to the influence of QoL factors. As stated in the results section, the statistically significant and deleterious effects of age on EFs were generally associated with a few QoL facets per executive variable. Namely, the moderators of age-related differences pertaining to the indicator of global EFs were environment and sensory abilities, those for the indicators of Shifting were environment and social participation, and physical health was bordering significance, and those for the indicators of Updating were environment and social relationships. Most notably, as many as five QoL variables were found to significantly moderate the relationship between age and the indicators of Inhibiting: environment, autonomy, death and dying, intimacy, and total QoL, while social relationships was bordering significance. Additionally, the QoL domains mentioned here only pertain to the moderation interactions and do not include the numerous QoL facets that uniquely predicted performance for various inhibitory indicators. These were also found to be in greater numbers for Inhibiting tasks than for other EFs.

Moreover, earlier it was shown that contrary to one of the study's major hypotheses, indicators of Inhibiting were not affected by age above and beyond other EFs. Inhibiting has been repeatedly said to play a pivotal role in changes associated with cognitive aging (e.g., Bell et al., 2008; Darowski et al., 2008; Hasher et al., 1991; Hasher et al., 1999; Hasher et al., 2007; Hasher & Zacks, 1988); it was therefore expected that it would display more vulnerability to age-effects than other EFs. Indicators of Inhibiting could not be confirmed to be the primary determinants of age-related cognitive deficits herein. Yet, the moderation analyses seem to support their sensitivity to processes throughout aging. The widespread unique and moderation interactions related to Inhibiting tasks uphold the existence of a unique relationship between older adult lifespan processes and inhibitory skills in our sample. More specifically, it appears that individual factors influencing our participants' perceptions of the environment, autonomy, death and dying, intimacy, total QoL, and potentially social relationships, may play a significant role over the ability to efficiently and deliberately ignore or suppress prepotent responses.

On one side, the detrimental effects of undesirable life situations (related to QoL) are known to interfere with reasoning, problem solving, remembering things, and the ability to exercise self-control (i.e., EFs; Diamond, 2013). Interestingly, endorsing more positive impressions of such life circumstances may have the reverse effect. As seen in the present study, more positive QoL ratings may indeed account for significant age-related differences in these abilities. A sensible explanation for this may be that the energy someone with unwelcome life circumstances expands to perform inhibitory tasks impacts performance efficiency and accuracy.

That is to say that if something pertaining to one's QoL is subjectively viewed as unsatisfactory, it most likely affects complex thinking skills such as EFs. This is without mentioning the added influence of normal aging processes over such skills. This claim was supported recently both behaviorally and electrophysiologically (i.e., event-related potentials; ERP) with regards to the harmful effects of experienced stress and decreased inhibitory task performance in older participants (compared to younger adults; Marshall, Cooper, & Geeraert, 2016). These findings correspond with ours. They also align with the previously considered value in investigating both neural and behavioral age-related effects of inhibitory control/compensation in older adults (Lustig & Jantz, 2015). Future empirical endeavors should ideally consider neural compensatory mechanisms relevant to inhibitory task performance and the association with multifaceted QoL moderators (beyond global stress, as per Marshall et al., 2016).

Overall, in the absence of robust support for *the inhibition deficit theory of cognitive aging*, this study showed that indicators of Inhibiting are likely more sensitive to some age-related effects than other EFs. More specifically, it has been outlined so far that a greater number of QoL domains were associated with inhibitory task performance and age, both as unique predictors and as moderators, compared to indicators of global EFs, Shifting and Updating. These findings provide further appeal to the hypothesized age-related vulnerability of this construct, as well as finding interventions that may improve Inhibiting through the manipulation of QoL variables.

Relationship between sensory abilities and EFs. Only the WHOQOL-BREF environment domain was found to significantly moderate one indicator for every executive component. Within the regression results however, another QoL facet was revealed to also affect all EFs constructs but at the individual predictor level (vs. moderation). More specifically, a statistically significant and positive correlation was noted between the WHOQOL-OLD sensory abilities domain and performance related to indicators of global EFs, Shifting (i.e., Local Global accuracy and RT), Updating (i.e., Keep Track accuracy and Number Letter RT), and Inhibiting (i.e., Stop Signal accuracy and RT). In this context, sensory abilities corresponded to the impact of loss of sensory abilities on QoL (i.e., impairments to senses affecting daily life, loss of sensory abilities affecting participation in activities, problems with sensory functioning affecting ability to interact, and rating of sensory functioning). As predicted, better or worse ratings regarding sensory abilities were suggested to significantly predict better or worse the aforementioned executive variables.

There exists at least one plausible explanation for the unique relationship between sensory abilities and EFs. It is possible for instance that, rather than truly impacting EFs, the integrity of visual, auditory, and tactile functions generally influences behavioral performance on computerized tasks. It could be that the efficiency of such functions affects task performance broadly, rather than being specifically related to EFs. Participants in this study were asked to confirm that they possessed adequate sensory abilities (i.e., adequate vision for the computerized tasks and hearing for the verbal task instructions provided by the examiner) required to engage in the executive testing however, both initially and throughout testing. Also, as mentioned in the methodology section, the font for the task instructions was drastically enlarged from previous versions to accommodate different visual needs. Further, controlling for the potential influence of processing speed over EFs, for which the effects can be difficult to distinguish from sensory functioning, was a central part of this study. At any rate, age-related declines in sensory abilities have been repeatedly postulated to alter how effectively older adults encode information on cognitive tasks (e.g., Craik & Rose, 2012; Grady & Craik, 2000; Wingfield, Tun, & McCoy, 2005). Changes in vision are said to affect processing of visual task stimuli, while diminished hearing is thought to impact how task instructions are processed and consequently remembered later on. Additionally, both of these factors can ultimately impact one's overall performance on complex cognitive tasks. In keeping with this, the modality by which EFs are assessed (e.g., visual computer testing) most likely influences one's performance to some extent. On the other hand, sensory skills are probably independently related to EFs per se and likely explain some of the variance founds with older adult samples, as illustrated by our findings.

Despite providing confirmation of the necessary sensory abilities, levels of visual and auditory functioning undoubtedly varied from one person to the next in this sample. Individual differences in sensory functions were not accounted for outside of QoL ratings for this domain. This potentially represents a limitation to this study and similar lines of enquiry. It could perhaps have been helpful to assess these skills outside of QoL ratings (e.g., testing sensory abilities per se). In fact, some have argued that specifically considering the effects of interactions between sensory and cognitive functions is essential to research in the field of cognitive aging (Wingfield et al., 2005).

Whatever the cause may be, the results herein shed light on the relationship between one's perception of the integrity and influence of sensory faculties over daily life activities and EFs. This interaction had significant effects over indicators related to all of the executive components measured herein and likely extends beyond participation in this study. As per the recommendation noted above, future research would benefit from considering different factors that may affect cognitive functioning in older adults, including but not limited to sensory functioning.

The notable relationship between social engagement and EFs. In the introduction, the plethora of empirical evidence for the association between higher levels of social engagement and cognitive benefits in older adults was discussed (e.g., Barnes et al., 2004; Bassuk et al., 1999; Ertel et al., 2008; Fratiglioni et al., 2004; Lövdén et al., 2005; James et al., 2011; Seeman et al., 2011). It was also outlined that whether this relationship extends to EFs or not is uncertain. Cognitive training research also provides some evidence for the advantages of social engagement in older adults over improving cognition (e.g., Haslam et al., 2010; Lampit, Hallock, & Valenzuela, 2014; Stine-Morrow, 2014) and preventing cognitive decline (e.g., as seen in a 2012 issue of Lancet Neurology aimed at finding strategies to prevent and effectively treat Alzheimer's disease by 2025). The extension of this social advantage to EFs is sensible. It provides an additional incentive to exploring social strategies aimed at maximizing cognition, health, and well-being in older adults further.

Associations between social engagement (as indicated by the social relationships and social participation domains) and particular indicators of EFs revealed by our analyses were perhaps not as robust as what others have found. The results revealed only two significant moderation effects (i.e., Keep Track accuracy and Number Letter RT, and bordering significance for Stop Signal accuracy with $p = .053$). In this context, social relationships referred to personal relationships, social support, and sexual activity, whereas social participation referred to current and potential opportunities for social interactions through community engagement. It should be noted that the direction of the interaction between age, social relationships, and Keep Track accuracy was unexpected. Task-specific effects underlying this moderation interaction, as well as the nature of particular social bonds will be discussed further below (see unexpected relationships section).

At any rate, even if a significant relationship was only noted for two of the executive indicators (i.e., Keep Track accuracy and Number Letter RT), social engagement may still represent an appealing area for cognitive interventions. More specifically, social engagement is likely one of the most cost-effective and accessible targets for interventions with older adults. Continued empirical investigations aimed at maximizing well-being and cognition in the growing older adult population is imperative.

Unexpected relationships. Most of the results described in this dissertation were in line with our hypotheses. When significant interactions were found between age and indicators of EFs, or age, EFs and QoL domains, they generally supported the hypothesized negative effect of older age on EFs and the aforementioned QoL *buffering interaction* (Cohen et al., 2003, 2013). Simply put, for most significant relationships, older age was associated with poorer or slower executive performance and higher QoL ratings with better EFs scores. Yet, some of our findings revealed unforeseen directions for particular significant associations between age, EFs, and QoL. The most unexpected association was noted for the interaction between age, social relationships, and Keep Track accuracy, mentioned above. Additionally, analyses for *the processing speed theory* and moderation interactions pertaining to Shifting indicators of RT were said to require a deeper understanding of 'shift costs' and the data themselves. These unexpected relationships will be explored next.

Effect of age and social relationships over Keep Track accuracy. The standardized regression coefficient for this interaction (i.e., -.258) suggested that an increase in values for age by social relationships was associated with a decrease in values for Keep Track accuracy. In other words, higher ratings in social relationships were associated with enhanced and lower age-related differences for Keep Track accuracy scores. Evidently, it was hypothesized that a reverse effect would be found (i.e., a buffering effect of QoL on age-related differences). While this finding may be associated with a Type I error, it is also possible that it is in fact related to the nature of the variables measured herein (i.e., ratings regarding social relationships and Keep Track accuracy scores). This will be discussed next.

Again, the scale tapping onto social relationships referred to personal relationships, social support, and sexual activity. Participants were asked to rate their satisfaction level with target items for the last two weeks. The robust association in the literature between higher levels of social engagement and cognitive benefits in older adults was mentioned several times in this dissertation. Nevertheless, when they were combined to age-related effects, ratings on this specific QoL scale were associated with decreased control over one's attention and the ability to effectively update the content of WM accordingly. One possible explanation that comes to mind is that even if some social relationships are deemed satisfactory, they may still be associated with higher stress and concern for the individuals involved. As noted by Umberson and Montez (2010), while social relationships are crucial to emotional support, they can still be very stressful and undermine health through various pathways. These authors also stated that some social relationships may have unintended negative effects, which they referred to as the "social contagion" impact some peers or loved ones can inadvertently have on others. In keeping with this and of interest here, assuming caregiving roles later in life (e.g., as a parent or husband/wife) is common and has been shown to be adversely associated with health in some individuals (e.g., Christakis & Allison 2006; Schulz & Sherwood 2008). Regarding the moderation findings, this effect may perhaps even be present when the target relationships are viewed as fulfilling. Despite the dominance of health-related investigations in this specific field of study, the potential cognitive disadvantages associated with caregiving have been explored by some. Namely, a small cross-sectional study (Oken, Fonareva, & Wahbeh, 2011) looking at the cognitive costs of stress in 31 dementia caregivers compared to a group of 25 non-caregiving controls, found that caregivers performed significantly worse than non-caregivers on two tasks of executive attention (i.e., the Stroop Color and Word Test and the Attention Network Task). Their results revealed that impaired sleep was the only mediator of the caregiver effect on cognitive performance compared to other variables such as perceived stress, depression, self-efficacy, and mindfulness. More evidence of the influence of caregiving over cognition in older adults is needed. Regardless, this study points to the possible underlying explanation for the unexpected moderation relationship discussed here. That is, the unforeseen and statistically significant moderating role of social relationships over age-related differences in Keep Track accuracy is perhaps related to caregiving stress. It is possible that some of the participants in our sample take-on stressful caregiving responsibilities. They may nevertheless view the associated relationships as satisfying. Yet, these relationships may be cognitively taxing and affect their ability to focus on complex attention-based tasks requiring WM skills. As explained before, the Keep Track task requires mental manipulation and categorization of information (i.e., WM). It is debatably more challenging than the other task used to indicate Updating in this study. In fact, although the Letter Memory task requires individuals to update the content of their WM based on new information presented on the screen (i.e., letters), it does not require stimuli categorization. The added categorization demands of the Keep Track task may make it more sensitive to deficits in Updating skills, that is when combined with social relationships ratings. This last point is important. The simple relationship between age and Keep Track accuracy scores is in the expected direction: older age was negatively associated with Keep Track accuracy scores. This relationship is illustrated in Figure 18 (i.e., the mean social relationships line, which shows the main effect of age on Keep Track accuracy, holding social relationships constant). It is only with the added effect of social relationships (i.e., hashed lines) that Keep Track accuracy declines significantly with age.

All in all, the relationship between social engagement and cognitive aging was not as clearly demonstrated by our analyses compared to previous studies. Nonetheless, a few significant moderating effects were revealed. Also, the last results outlined here may be due to a Type I error. Conversely, external and confounding variables may very well explain this surprising effect (e.g., caregiver responsibilities impairing WM skills). All in all, further exploring this relationship with a larger sample, added demographic variables (e.g., presence of caregiving duties), and alternative measures of WM is needed.

Effect of age over RT 'shift costs'. Results for RT indicators of Shifting related to *the processing speed theory* and QoL-moderation interactions revealed a somewhat intriguing effect. As mentioned earlier, at first glance, some of the findings for these indicators seemed to reflect significantly better/faster RTs (i.e., decreasing) with older age. Slopes for some Shifting tasks suggested that older participants had significantly smaller RTs compared to younger individuals. Average 'shift costs' (vs. mean RT) however were calculated to represent RT for the Local Global and Number Letter tasks. These 'shift costs' were based on RT differences between executive and non-executive blocks. Initially, it was expected that the 'cost' associated with Shifting would be greater with older age. It was expected that older age would be associated with larger/slower RTs on the third-executive block, which would subsequently impact 'shift costs'. This may be an oversimplified interpretation of 'shift costs' however, and a closer look at the relevant literature may clarify this unexpected effect.

Previously, 'shift costs' (Huff et al., 2015; Rogers & Monsell, 1995) were said to reflect processes associated with maintaining and switching between multiple task configurations across trials. Based on this definition and as noted above, one may assume that the 'cost' of task-shifting would increase with older age. Yet, looking at the significant results outlined earlier revealed increasingly smaller 'shift costs' in older participants (see Tables 3 and 4 and Figures 4, 5, 14-17). Overall, older age was associated with reduced differences between blocks related to RT (i.e., 'shift costs'). Perhaps this effect relates to the notion that younger individuals generally benefit from initial learning trials (e.g., the first two non-executive blocks on a task) to improve future performance (e.g., the final and executive block) to a greater extent than older adults (Mahncke, Bronstone, & Merzenich, 2006). In line with this, younger participants could be expected to show greater RT differences across trials, as their performance on later blocks would significantly differ and benefit from practice on earlier blocks (i.e., resulting in larger 'shift costs'). On the other hand, older participants could be expected to show smaller RT differences across trials, as their performance on later blocks would not significantly improve or differ from previous blocks (i.e., resulting in smaller 'shift costs'). A study cited previously (Crevier-Quintin, 2013) comparing younger, middle-aged, and older adults on five EFs tasks did find that older participants did not benefit from initial learning blocks as much as younger participants on the Raven's Advanced Progressive Matrices. This finding was reflected in larger benefits and improved performance on later-executive blocks in younger vs. older participants. Although the task mentioned here is not typically thought to tap onto Shifting skills, it is structured similarly to the Local Global and Number Letter tasks and is also increasingly challenging across blocks.

More closely related to the present endeavor, a recent study (Huff et al., 2015) specifically investigated 'shift costs' (described as 'switch costs') across younger, middle-aged, older adults, and individuals with very mild Alzheimer's disease. Their multifaceted assessment distinguished 'local costs' (comparing switch vs. nonswitch trials) from 'global costs' (comparing nonswitch vs. pure trials) however, for which mean error rates, mean response latencies, underlying RT distributions, and stimulus-response congruency effects were calculated. In this context, the pure trials consisted of single-task trials comparable to the first and second non-executive blocks of the present Shifting tasks, whereas the switch block consisted of nonswitch and switch trials, comparable to the third executive block. Of interest here, these authors found that 'global costs' significantly increased with age, while 'local costs' significantly reduced with age. These results were interpreted in the context of changes in learning proficiency and flexibility with age. Specifically, regarding 'global costs', they were said to increase with age due to the added challenges of maintaining two task sets at once on the shift block, which would be costlier for older adults' "compromised attentional systems". As for 'local costs', these authors stated that compared to older adults and individuals with very mild Alzheimer's disease, younger adults "are more likely to become well-tuned to a given task set and therefore when the task set changes, inertia from the previous task set slows the reconfiguration needed to respond to the switch trial" (p.735). They further suggested that older adults have "less well-tuned systems" and are more likely to keep both task sets active between switch vs. nonswitch trials, which explains the reduction in 'local costs'. Despite the debatable complexity of these findings, there may be value in interpreting the current lowered 'shift costs' with older age as resulting from "less well-tuned systems" and continuously active sets. Consistent with this study and other examples mentioned earlier, the effect of older age on reduced 'shift costs' may be interpreted as age-related differences in learning ability, flexibility, and efficiency. Again, these findings are likely due to differences in the ability to improve performance throughout a task, which is negatively associated with aging.

Further investigations of 'shift cost' processes across the older adult lifespan are needed to gain a richer understanding of such age-related differences. Including additional indicators of RT for Shifting measures in future endeavors may also be valuable. The present results nevertheless point to the potential impact of aging over task-set switching (Shifting) and the inherent complexity of age-related differences in EFs.

Other relationships between QoL and EFs. Finally, the moderation analyses shown herein outlined several additional associations between single executive and QoL indicators. Namely, the following QoL domains were significantly found to each moderate one executive indicator and have not been explicitly mentioned outside of the results section. For the WHOQOL-BREF: physical health moderated age-related effects on Number Letter RT (Shifting indicator); for the WHOQOL-OLD: autonomy on Go/No Go RT (Inhibiting indicator), death and dying on Stop Signal accuracy (Inhibiting indicator), and intimacy on Go/No Go accuracy (Inhibiting indicator). It was discussed earlier however, that the majority of these significant moderation interactions pertained to indicators of Inhibiting, and implications related to this domain were explored above.

First, the moderating effects of physical health and autonomy/independence over cognition are in keeping with existing findings mentioned in the introduction (e.g., Brown et al., 2004; Fernández-Ballesteros, 2011; Gabriel & Bowling, 2004). The extant literature supports the general association of these domains with cognition in older adults, while the present study points to their specific relationship to indicators of Shifting and Inhibiting respectively. It was also suggested earlier that empirical evidence connecting a multidimensional construct of QoL (versus HQoL) to older adulthood was sparse. The current study addressed this issue by utilizing the WHO's older adult-specific definition and measurement of QoL which encompassed 11 facets.

Second and as noted above, perceptions about death and dying and opportunities for intimacy were also significant moderators of EFs specifically related to indicators of Inhibiting. More importantly, both domains seemed to be anecdotally related in this sample. That is, many participants shared with the examiner that answering QoL questions related to intimacy and death and dying was particularly challenging for them. Generally, these participants explained that this was because they were widowed and no longer felt they encountered intimacy in their personal lives. As seen in Table 1, almost 15% of the sample identified as widowed. It is possible that for some participants, perceptions around death and dying and intimacy shared the underlying theme of limited opportunities and end of life, which in turn was a moderating factor for inhibitory control accuracy on some tasks. The theoretical association between these variables is likely not as straightforward as others but nonetheless emphasizes the meaning of subjective perceptions over the preservation of complex thinking skills. To our knowledge, there does not seem to be specific literature on the association between these QoL variables and Inhibiting in older adults. In any case, perhaps what is of most interest here is not which QoL facets were related to which EFs; rather, the emphasis should be placed on the fact that individual appraisals for multiple QoL domains significantly impacted age-related differences in EFs in this sample.

Overall, moderation associations between the WHO QoL domains and age-related differences in EFs were found to be manifold. Several patterns connecting specific QoL facets and executive indicators were revealed and explored in relation to the extant literature. As predicted, the results described herein suggested that the buffering effect of higher QoL over declines in EFs in older adults is indeed significant for some domains, while one surprising exception was found and discussed above.

Examining the Role of Education, Marital Status, Illness, and Gender over EFs and QoL

MANCOVA analyses examining the relationships between various demographic variables (i.e., education, marital status, illness, and gender), EFs, processing speed, and QoL revealed several significant relationships. Higher education was associated with faster processing speed. This is consistent with current research on the relationship between demographic factors and cognition in older adults (Rexroth et al., 2013). Higher education also significantly correlated with positive appraisals of death and dying. These results are also consistent with recent research utilizing the WHOQOL-OLD among hospitalized and medically ill older adults (Saraçlı et al., 2015). The last cited study attributed the relationship between education and end of life perspectives to better social relationships and intellectual capacity.

Moreover, not surprisingly, being married or living as married was associated with significantly higher intimacy values compared to being divorced or widowed. Also somewhat predictable, participants who reported having a major illness endorsed significantly lower values for the physical health domain, as well as for social relationships, past, present, and future activities, death and dying, intimacy, and total QoL, compared to participants who reported no major illness.

Further, women performed significantly better/more accurately than men for the indicator of global EFs and one indicator of Updating (i.e., Letter Memory accuracy), while men performed significantly better/faster than women for on one indicator of Inhibiting (i.e., Go/No Go RT). A 2016 study (McCarrey, An, Kitner-Triolo, Ferrucci, & Resnick) showed that after adjusting for age, education, and cultural background, females outperformed males on most cognitive tests (including EFs). Their results also suggested steeper rates of decline over time for males on some measures (i.e., mental status, perceptuomotor speed and integration, and visuospatial ability), whereas there were no measures for which females showed significantly steeper declines. Our results do not support comparably drastic gender differences in EFs. They do show nonetheless that some task-specific differences may exist.

Finally, men endorsed significantly higher values than women for the psychological (i.e., perceptions regarding bodily image, self-esteem, cognitive abilities, negative and positive feelings) and intimacy domains. Regarding the psychological domain results, they appear to parallel a study which utilized the WHOQOL-BREF with 262 Swiss French speaking older adults (von Steinbüchel, Lischetzke, Gurny, & Eid, 2006). These authors found that females endorsed significantly more negative feelings than males. Regarding the intimacy results, as indicated previously, some participants noted that rating these items was challenging as many of them were widowed. Anecdotally, more females than males brought this issue to the attention of the examiner. This may potentially be linked to the fact that women generally live longer than men and consequently often outlive their male partners (Statistics Canada, 2012).

Overall, advantages associated with different levels of education, marital status, illness, and gender were revealed by our analyses. These findings further reinforce the powerful influences some internal and external factors, including but not limited to QoL, may have over cognitive aging and well-being later in life.

Conclusion

Final Words on the Relationships Between EFs, QoL, and Aging

This dissertation aimed to shed light on the vulnerability of complex cognitive skills to aging, factors related to QoL in older adulthood and, more importantly, the potential moderating role of QoL over EFs in older adults. It was hypothesized that QoL would significantly moderate the degree of age-related differences in performance on all executive tasks in our sample. In keeping with this, better or worse ratings for physical health, psychological status, environment, sensory abilities, autonomy, past, present, and future activities, social activities and participation, death and dying, and intimacy were predicted to buffer or enhance the extent of normative age-related differences associated with 13 indicators of executive accuracy and RT, related to global EFs, Shifting, Updating, and Inhibiting. Due to the known impact of aging over EFs, the variability in and importance of QoL in older adulthood, and the impact of life circumstances over cognitive abilities, the overarching goal was to determine *if and how QoL moderates the magnitude of EFs differences in old age*.

While statistically significant effects were not found for all indicators of QoL and EFs, several moderation interactions were revealed by our analyses. Numerous QoL domains did indeed significantly moderate age-related differences for various indicators of EFs. Namely, the prevalent influence of environmental factors over EFs was discussed. This was the only QoL domain that significantly moderated one indicator for each of the three EFs components as well as global EFs. Living circumstances and access to services were suggested to be important targets for the continued development of prevention and intervention endeavors in older adults. Next, the prevalent susceptibility of indicators of Inhibiting to QoL influences was explored. Five QoL variables were found to significantly moderate the relationship between age and indicators of Inhibiting. Additionally, numerous QoL facets were found to uniquely predict performance for various inhibitory measures. There was a larger number of relationships between QoL domains and indicators of Inhibiting than any other executive construct. These findings were said to be in support of the hypothesized age-related vulnerability of Inhibiting. Further, the role of sensory abilities as a unique predictor of multiple indicators of EFs was addressed. It was said that considering relationships between sensory and cognitive functions is essential to research in the field of cognitive aging and that future studies may wish to include objective measures of sensory ability. Moreover, it was noted that the association between social engagement and EFs was not as strongly demonstrated by our results compared to previous research. Nonetheless, a few significant moderation interactions did exist for measures of social engagement and indicators of EFs; one of them was even revealed to contradict our predictions. Specifically, the deleterious association between social relationships and age, over differences in Keep Track accuracy, was unforeseen. In line with this, the possibly negative influence of some relationships over cognition in older adults (i.e., caregiving) was mentioned. Investigating additional covariates pertaining to such relationships in future studies was suggested. Finally, a review of other unique moderation interactions was included. All in all, congruent with our hypotheses, multifaceted connections between indicators of QoL and EFs were repeatedly indicated by our analyses. A deeper search for influential factors related to QoL in older adults presents great appeal for future research and the development of policies and intervention programs.

A secondary goal of this dissertation was to reconcile prominent theories of cognitive aging and to approach the question of age-related differences in EFs with an integrative perspective. Based on recent reviews of these theories, it was hypothesized that *the processing* *speed theory* (Salthouse, 1996) and *the dedifferentiation hypothesis* (Garrett, 1946) would not be supported by our analyses, whereas *the inhibition deficit theory of cognitive aging* (Hasher & Zacks, 1988) would be. While processing speed did contribute to task performance on some measures of EFs, *the processing speed theory* was generally not supported by our findings. Only one (out of 13) indicators of EFs was found to be associated with processing speed above and beyond age-related effects. This suggested that the majority of variance in age-related differences in EFs could not be attributed to slowed processing speed in this sample. The indicator that was used for processing speed was argued to potentially confound these findings. A multifaceted representation of this construct was suggested for future endeavors. Next, contrary to what was predicted, *the inhibition deficit theory of cognitive aging* was not supported in the current study. Potential limitations for finding results comparable to the dominant literature included sample characteristics and the nature of the tasks. More specifically, the current study was unlike most research looking at aging-effects over Inhibiting, as it focused on the older adult lifespan instead of comparing younger and older adults. Also, it was suggested that some of the tasks used here were perhaps less behaviorally-sensitive (vs. "sensory-stimulus" related) than others, as argued in the literature. Specifically, compensatory neural mechanisms relevant to inhibitory task performance may confound our results. Finally, regarding *the dedifferentiation hypothesis*, all executive accuracy measures were found to remain significantly diverse with age after accounting for processing speed. Two pairs of executive RT measures however were found to be significantly more united as a function of age, as supported by *the dedifferentiation hypothesis*. This last finding goes against the dominant literature and our hypothesis. Similarities between the significantly correlated measures were considered to better understand these results. As it will be discussed shortly, limitations pertaining to task-specific effects are important to consider in studies like the present one.

The last part of this dissertation explored advantages associated with different covariates. Overall, it was found that together, QoL variables, education, marital status, illness, and gender may act as powerful influences over higher-order cognitive skills. Such influences may represent useful targets for studies aimed at promoting well-being and cognition later in life.

Limitations

This study had some limitations, most of which were previously mentioned. First, as cognitive screeners were not administered to our participants, self-report was used to assess if participants were cognitively healthy and met the eligibility criteria outlined previously. Future research may wish to include brief screening tools for mild cognitive impairment such as the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) to further ensure participants' eligibility/cognitive status.

Next, our relatively small sample size represents another limitation. It is necessary to gather rich data with relatively small sample sizes like the present in order to detect statistically significant effects and to obtain reliable estimates of the parameters. While we did consider over 20 factors associated with both QoL and EFs, a risk associated with Type I errors was present. Specifically, running multiple regression analyses with a small sample as well as including multiple predictors in a given model may inflate the risk for this type of statistical error (Cohen et al., 2013). Nonetheless, some measures were taken to improve interpretability of the results and assess the statistical soundness of the analyses, including but not limited to a preliminary G*Power analysis. As mentioned earlier for instance, the QoL and age variables were centered to reduce potential multicollinearity effects and to facilitate intercept interpretations (Cohen et al., 2003; Cohen et al., 2013). Recommended procedures were also used to deal with outliers and missing data (Tabachnick & Fidell, 2001).

Next, the specificity of some statistically significant effects was noted earlier and may represent a limitation to this study; that is, some relationships between age, indicators of EFs and QoL were constrained to single variables. Some moderation interactions for instance were limited to one indicator of QoL and one indicator of EFs, which limits the generalizability of some of the results. On one hand, our findings certainly appeared to support a variety of connections between these variables; on the other, the robustness underlying some of the relationships seemed to vary (in line with the number of associated indicators/predictors). Nonetheless, the results were discussed with this limitation in mind and an emphasis was placed on the overarching aim of this study: to investigate the existence of a link between aging, EFs, and QoL. The dearth of such research was at the heart of this objective and motivated this empirical endeavor.

Lastly, one more limitation was acknowledged in this dissertation. In keeping with task-specific effects, support for and against the theories of EFs investigated herein was said to be confounded by the measures we utilized. Selecting additional indicators of processing speed and Inhibiting for instance, may have yielded different results (regarding *the processing speed theory* and *the inhibition deficit theory of cognitive aging*). Although the indicators that were chosen for the present study were in line with the relevant literature, a recommendation was made to broaden processing speed and Inhibiting measures in future studies. Finally, a suggestion was also provided regarding alternative statistical approaches. Namely, confirmatory factor analysis may be appealing for researchers interested in evaluating models of EFs and latent factors, as per the work of Miyake and colleagues (2000) for instance. Although doing so did not represent a target for this study, it may provide useful information regarding age-related differences in EFs variables and the impact of QoL on such conceptualizations.

The Importance of Promoting Cognitive Health and Well-Being in Older Adults

The findings described herein illustrated the specificity and complexity of age-related processes in complex cognitive skills across the older adult lifespan. It was argued that utilizing an approach focused on this age group is likely more appropriate for these types of research questions, as opposed to comparing older adults to college students. To our knowledge, much of the relevant literature has focused on comparing EFs in these groups, as opposed to surveying cognition across older adulthood. Further, understanding the impact of subjective QoL ratings on executive age-related differences was the chief goal here. As stated earlier, the physiological and structural changes associated with aging and EFs are thought to have consequences on most aspects of everyday life (Diamond, 2013, 2014). Correspondingly, individual, internal and external factors are thought to have greater beneficial and adverse effects on these functions than other cognitive skills.

Finally, older adults represent the fastest growing population in Canada (Statistics Canada, 2015). Aging is a normal part of life and studying it represents a critical and emerging issue in our society. Fortunately, despite multidimensional age-related losses, subjective well-being seems to remain relatively high throughout older adulthood (see The Paradox of Aging; Samanez-Larkin et al., 2014). The degree of independence and productivity maintained by older individuals however is thought to significantly suffer from the aforementioned cognitive age-effect (e.g., Bell-McGinty et al., 2002; Jefferson, et al., 2006). Given the exorbitant costs of physical and mental health in older adults, it is essential to utilize research to guide prevention and remediation efforts. Specifically, it is imperative to gain a richer appreciation of the unique factors that contribute to preserving or improving complex thinking abilities and overall well-being later in life. The present dissertation was produced in an effort to contribute to this body of literature.

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Appendix A. Screener Questionnaire

This form includes questions pertaining to your demographic information (i.e., gender, age, etc.), health history (i.e., medical conditions, mental health problems), neurologic history (e.g., traumatic brain injury, stroke, multiple sclerosis, epilepsy, chronic migraines diagnoses), and health-related behaviours (i.e., exercise routine).
Please answer all the questions. If you are unsure about which response to give to a question, please choose the one that appears most appropriate. This can often be your first response.

Name:________________________ Participant Number (*provided by researcher*):___________

Age:____ **Gender:** M F

Handedness: Right Left **Ethnicity:** _________________

Do you have normal vision? Yes No

Do you have normal hearing? Yes No

Has a physician ever diagnosed you with any neurological conditions (e.g., traumatic brain injury, stroke, multiple sclerosis, epilepsy, chronic migraines)? Yes No

Has a physician ever diagnosed you with any mental health conditions (e.g., depression, anxiety, panic disorder, learning disorder, ADHD, schizophrenia)? Yes No

Are you currently taking any prescription medication? Yes No

- If YES, which type of medication:
- How often do you take it:
- How much do you take each time:

Have you consumed any alcohol in the past 48 hours? Yes No

- Please Specify approximately how much:

Are you Bilingual? Yes No
If yes, please respond to the questions below:

What is your native language (L1)? _________________________

Please list any other languages that you know below. For each, rate how well you can use the language on the following scale (from 1-5): Not Good 1 2 3 4 5 Close to Native

Languages	**Speaking**	**Understanding**	**Writing**	**Reading**
L2:				
L3:				

Physical Activity Levels

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. **Please answer each question even if you do not consider yourself to be an active person.**

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities?

   _____ days per week **If you performed no vigorous physical activities, skip to question 3.*

2. How much time did you usually spend doing vigorous physical activities on one of those days?

   _____ hours per day _____ minutes per day Don't know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities? Do not include walking.

   _____ days per week **If you performed no moderate physical activities, skip to question 5.*

4. How much time did you usually spend doing moderate physical activities on one of those days?

   _____ hours per day _____ minutes per day Don't know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

   _____ days per week **If you performed no walking, skip to question 7.*

6. How much time did you usually spend walking on one of those days?

   _____ hours per day _____ minutes per day Don't know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time.

7. During the last 7 days, how much time did you spend sitting on a weekday?

   _____ hours per day _____ minutes per day Don't know/Not sure

Appendix B. WHOQOL-BREF and OLD

MSA/MNH/PSF/97.6
Page 2

I.D. number

ABOUT YOU

Before you begin we would like to ask you to answer a few general questions about yourself: by circling the correct answer or by filling in the space provided.

What is your **gender**? Male Female

What is you **date of birth**? ________ / ________ / ________
Day / Month / Year

What is the highest **education** you received?
None at all
Primary school
Secondary school
Tertiary

What is your **marital status**?
Single
Married
Living as married
Separated
Divorced
Widowed

Are you currently **ill**? Yes No

If something is wrong with your health what do you think it is?___________________________illness/ problem

Instructions

This assessment asks how you feel about your quality of life, health, or other areas of your life. **Please answer all the questions.** If you are unsure about which response to give to a question, **please choose the one** that appears most appropriate. This can often be your first response.

Please keep in mind your standards, hopes, pleasures and concerns. We ask that you think about your life **in the last two weeks.** For example, thinking about the last two weeks, a question might ask:

		Not at all	Not much	Moderately	A great deal	Completely
	Do you get the kind of support from others that you need?	1	2	3	4	5

You should circle the number that best fits how much support you got from others over the last two weeks. So you would circle the number 4 if you got a great deal of support from others as follows.

		Not at all	Not much	Moderately	A great deal	Completely
	Do you get the kind of support from others that you need?	1	2	3	4	5

You would circle number 1 if you did not get any of the support that you needed from others in the last two weeks.

Please read each question, assess your feelings, and circle the number on the scale for each question that gives the best answer for you.

		Very poor	Poor	Neither poor nor good	Good	Very good
1(G1)	How would you rate your quality of life?	1	2	3	4	5

		Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
2 (G4)	How satisfied are you with your health?	1	2	3	4	5

The following questions ask about **how much** you have experienced certain things in the last two weeks.

		Not at all	A little	A moderate amount	Very much	An extreme amount
3 (F1.4)	To what extent do you feel that physical pain prevents you from doing what you need to do?	1	2	3	4	5
4(F11.3)	How much do you need any medical treatment to function in your daily life?	1	2	3	4	5
5(F4.1)	How much do you enjoy life?	1	2	3	4	5
6(F24.2)	To what extent do you feel your life to be meaningful?	1	2	3	4	5

		Not at all	A little	A moderate amount	Very much	Extremely
7(F5.3)	How well are you able to concentrate?	1	2	3	4	5
8 (F16.1)	How safe do you feel in your daily life?	1	2	3	4	5
9 (F22.1)	How healthy is your physical environment?	1	2	3	4	5

The following questions ask about **how completely** you experience or were able to do certain things in the last two weeks.

		Not at all	A little	Moderately	Mostly	Completely
10 (F2.1)	Do you have enough energy for everyday life?	1	2	3	4	5
11 (F7.1)	Are you able to accept your bodily appearance?	1	2	3	4	5
12 (F18.1)	Have you enough money to meet your needs?	1	2	3	4	5
13 (F20.1)	How available to you is the information that you need in your day-to-day life?	1	2	3	4	5
14 (F21.1)	To what extent do you have the opportunity for leisure activities?	1	2	3	4	5

		Very poor	Poor	Neither	Good	Very good

				poor nor good		
15 (F9.1)	How well are you able to get around?	1	2	3	4	5

The following questions ask you to say how **good or satisfied** you have felt about various aspects of your life over the last two weeks.

		Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
16 (F3.3)	How satisfied are you with your sleep?	1	2	3	4	5
17 (F10.3)	How satisfied are you with your ability to perform your daily living activities?	1	2	3	4	5
18(F12.4)	How satisfied are you with your capacity for work?	1	2	3	4	5
19 (F6.3)	How satisfied are you with yourself?	1	2	3	4	5
20(F13.3)	How satisfied are you with your personal relationships?	1	2	3	4	5
21(F15.3)	How satisfied are you with your sex life?	1	2	3	4	5
22(F14.4)	How satisfied are you with the support you get from your friends?	1	2	3	4	5
23(F17.3)	How satisfied are you with the conditions of your living place?	1	2	3	4	5
24(F19.3)	How satisfied are you with your access to health services?	1	2	3	4	5
25(F23.3)	How satisfied are you with your transport?	1	2	3	4	5

The following question refers to **how often** you have felt or experienced certain things in the last two weeks.

		Never	Seldom	Quite often	Very often	Always
26 (F8.1)	How often do you have negative feelings such as blue mood, despair, anxiety, depression?	1	2	3	4	5

Did someone help you to fill out this form?..

How long did it take to fill this form out?..

Do you have any comments about the assessment?

....

....

THANK YOU FOR YOUR HELP

The following questions ask about how much **you have experienced certain things in the last two weeks, for example, freedom of choice and feelings of control in your life. If you have experienced these things an extreme amount circle the number next to "An extreme amount". If you have not experienced these things at all, circle the number next to "Not at all". You should circle one of the numbers in between if you wish to indicate your answer lies somewhere between "Not at all" and "Extremely". Questions refer to the last two weeks.**

1. (F25.1) To what extent do impairments to your senses (e.g. hearing, vision, taste, smell, touch) affect your daily life?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

2. (F25.3) To what extent does loss of for example, hearing, vision, taste, smell or touch affect your ability to participate in activities?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

3. (F26.1) How much freedom do you have to make your own decisions?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

4. (F26.2) To what extent do you feel in control of your future?

Not at all	Slightly	Moderately	Very	Extremely
1	2	3	4	5

5. (F26.4) How much do you feel that the people around you are respectful of your freedom?

Not at all	Slightly	Moderately	Very	Extremely
1	2	3	4	5

6. (F29.2) How concerned are you about the way in which you will die?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

7. (F29.3) How much are you afraid of not being able to control your death?

Not at all	Slightly	Moderately	Very	Extremely
1	2	3	4	5

8. (F29.4) How scared are you of dying?

Not at all	Slightly	Moderately	Very	Extremely
1	2	3	4	5

9. (F29.5) How much do you fear being in pain before you die?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

The following questions ask about how completely **you experience or were able to do certain things in the last two weeks, for example getting out as much as you would like to. If you have been able to do these things completely, circle the number next to "Completely". If you have not been able to do these things at all, circle the number next to "Not at all". You should circle one of the numbers in between if you wish to indicate your answer lies somewhere between "Not at all" and "Completely". Questions refer to the last two weeks.**

10. (F25.4) To what extent do problems with your sensory functioning (e.g. hearing, vision, taste, smell, touch) affect your ability to interact with others?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

11. (F26.3) To what extent are you able to do the things you'd like to do?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

12. (F27.3) To what extent are you satisfied with your opportunities to continue achieving in life?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

13. (F27.4) How much do you feel that you have received the recognition you deserve in life?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

14. (F28.4) To what extent do you feel that you have enough to do each day?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

The following questions ask you to say how satisfied, happy or good **you have felt about various aspects of your life over the last two weeks . For example, about your participation in community life or your achievements in life. Decide how satisfied or dissatisfied you are with each aspect of your life and circle the number that best fits how you feel about this. Questions refer to the last two weeks.**

15. (F27.5) How satisfied are you with what you have achieved in life?

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
1	2	3	4	5

16. (F28.1) How satisfied are you with the way you use your time?

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
1	2	3	4	5

17. (F28.2) How satisfied are you with your level of activity?

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
1	2	3	4	5

18. (F28.7) How satisfied are you with your opportunity to participate in community activities?

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
1	2	3	4	5

19. (F27.1) How happy are you with the things you are able to look forward to?

Very unhappy	Unhappy	Neither happy nor unhappy	Happy	Very happy
1	2	3	4	5

20. (F25.2) How would you rate your sensory functioning (e.g. hearing, vision, taste, smell, touch)?

Very poor	Poor	Neither poor nor good	Good	Very good
1	2	3	4	5

The following questions refer to any intimate relationships **that you may have. Please consider these questions with reference to a close partner or other close person with whom you can share intimacy more than with any other person in your life.**

21. (F30.2) To what extent do you feel a sense of companionship in your life?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

22. (F30.3) To what extent do you experience love in your life?

Not at all	A little	A moderate amount	Very much	An extreme amount
1	2	3	4	5

23. (F30.4) To what extent do you have opportunities to love?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

24. (F30.7) To what extent do you have opportunities to be loved?

Not at all	A little	Moderately	Mostly	Completely
1	2	3	4	5

Do you have any comments about the questionnaire?

THANK YOU FOR YOUR HELP