Does a Purposeful Life Mean a Healthy Life? Evaluating Longitudinal Associations between Sense of Purpose, Cognition, and Health

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Abstract

Sense of purpose in life, or the view that one's life has direction and is guided by overarching life aims, has been found to predict better health outcomes across the adult lifespan, including better cognitive functioning and dementia risk, physical health, and improved longevity. This research is based on multi-study replications of large longitudinal datasets, as well as intensive measurement design to examine short-term (e.g., within-day, day-to-day) and long-term (years) associations between sense of purpose and markers of cognition and health. The first project used multistate survival modeling to evaluate the role of sense of purpose on transitions across cognitive states and death and was based on two large longitudinal datasets – the Rush Memory and Aging Project (MAP) and the Health and Retirement Study (HRS). More purposeful older adults were found to have lower prospective risk of developing mild cognitive impairment (and equivalent classification in HRS), later onset of impairment, and increased likelihood of improvement in cognitive functioning following MCI classification. These results were replicated across two independent longitudinal studies with disparate samples and measurement procedures. The second project examined longitudinal associations between sense of purpose in life and allostatic load in two nationally representative samples of American (HRS) and English (English Longitudinal Study of Ageing; ELSA) adults over age 50. Blood-based biomarkers of cardiovascular, metabolic, immune, and renal function, as well as anthropometric and physical markers such as lung function were used to compute overall scores representing allostatic burden. Sense of purpose in life was associated with lower overall level of allostatic load across measurement occasions in the two samples but did not predict rate of change or within-person fluctuations in allostatic burden across time. The third study investigated daily variations in sense of purpose and associations with daily cognitive performance using an ecological momentary assessment design. Multilevel models examined within- and between-person associations between end of day sense of purpose ratings and performance on five indices of cognitive functioning. Results showed no associations between daily ratings of purposefulness and performance on five cognitive tasks across a two-week period. Taken together, these findings advance existing theory and highlight important directions for the field moving forward.

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> Diplomas — there will only be one name and this is yours, but I hope it doesn't confuse you and you think that maybe you made it that far by yourself. No, you didn't. It took a lot of help. None of us can make it alone. But this is so important for you to understand. I didn't make it that far on my own. I mean, to accept that credit or that medal, would discount every single person that has helped me get here today, that gave me advice, that made an effort, that lifted me up when I fell. And it gives the wrong impression that we can do it all alone. None of us can. The whole concept of the self-made man or woman is a myth. (Arnold Schwarzenegger, "None of us can make it alone", University of Houston Graduation Speech, 12 May 2017)

Like the great Arnold Schwarzenegger, there are so many people who have helped lift me up throughout my journey, without whom I would not be in the position I am now. It is hard to put into words the multitude of feelings I am experiencing as I near the end of my doctoral training, but most of all I would like to express my gratitude for the kindness and support I have received. First, I would like to thank my parents, Tod and Debbie, for their constant support and dedication to helping me grow as a person. It has been a great comfort to me knowing that wherever I am in the world, my own personal cheerleaders are just a phone call away and willing to listen and empathise with whatever situation I am dealing with. I am truly lucky to have parents as thoughtful and supportive as you, even if you are ruthless landlords. I would also like to thank Raven McCallum, whose unwavering support has kept me going through some difficult times and moments of seemingly overwhelming stress. Your resilience and kindness are an inspiration, and I cannot thank you enough. I would also like to acknowledge my pets, Finn, Xander, and Prawn, for helping me unwind and realize there is more to life than work. And thank you to Peter Treboutat, who despite an over 4500km distance between us, has remained my closest friend. Your thoughtfulness, humour, and encouragement has been foundational in helping me become the person I am today. I look forward to sharing many more years of friendship, laughter, and nerdy activities together.

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Chapter 1 – General Introduction

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*This introductory chapter is based, in part, on my original contributions to this co-authored chapter (50%) in addition to original material defining purpose in life and discussing its development and research history.

Longitudinal Stability and Change in Sense of Purpose in Life

Purpose is a dynamic construct that fluctuates in prevalence throughout the lifespan, but consistently predicts desirable outcomes regardless of one's age. *Sense of purpose* can be understood as the extent to which one feels that they have personally meaningful goals and directions guiding them through life (Ryff, 1989), while a *purpose in life* refers to those specific goals and directions (McKnight & Kashdan, 2009). Purpose is not viewed as simply a goal one must achieve before moving onto another, but an overarching theme that penetrates the various smaller obtainable goals that one pursues throughout their lives (Kashdan & McKnight, 2013; Lewis, 2020). Whereas adolescence and emerging adulthood are viewed as periods of fluidity with regard to purpose exploration, adulthood is typically marked by greater stability in sense of purpose over time. However, several studies have suggested that sense of purpose in life begins to decline in the latter half of the lifespan, with older adults showing diminished purposefulness compared to younger counterparts. A meta-analysis of over 70 studies on sense of purpose in middle and older adulthood reported a small age-related decline in sense of purpose beginning in midlife, with these changes being more pronounced following retirement age (Pinquart, 2002). One potential explanation for this trend is that purpose is closely tied to our major life roles, which may decrease with advancing age and after retirement. Older individuals often face numerous unique challenges to their purpose such as retirement, declining health or functional ability, widowhood, and changes in social structure. Each of these events has the potential to influence the type of goal pursuits in which an individual engages, and therefore, the loss of these could lead to a less salient sense of purpose in older individuals.

However, a major limitation of this area has been the reliance on cross-sectional data. The studies synthesized in the above meta-analysis each report mean-level differences between younger and older age groups, but do not reflect how sense of purpose may change within individuals over time. This is concerning as cross-sectional comparisons across age-heterogeneous samples may greatly inflate age-related effects and do not account for the influence of between-cohort differences (Hofer & Sliwinski, 2001). As such, longitudinal designs are needed to make claims about within-person changes in purpose over time. More recent research using longitudinal data has found that sense of purpose does decline with advancing age, though this is not the case for all individuals. Using two large longitudinal studies, Springer and colleagues (2011) examined change in sense of purpose across a 10-year interval in young, middle, and older adult age cohorts. They observed a small decline in sense of purpose between assessments, particularly among the oldest age group. Similarly, Hill and colleagues (2015) assessed within-person changes in sense of purpose among older men across a three-year span but found little mean-level change over time. Finally, based on participants over age 50 from the Health and Retirement Study (HRS), individuals experienced a mean-level decline in sense of purpose over an eight year period, though there was significant individual-level variability in purpose change over time (Hill & Weston, 2019). An important finding in these studies is that there is considerable heterogeneity in the changes in sense of purpose of adults over time. In other words, though purposefulness may show slight mean-level declines approaching older adulthood, not everyone follows this trend—many individuals show relative stability or even growth in purposefulness over time.

Given the differences in individual trajectories of purpose change, an emerging literature has sought to examine factors that may influence how individuals change in purpose over time. One such precipitating factor may be physical health, as many studies have reported that better health and physiological functioning are associated with higher sense of purpose (see Pinquart, 2002). Declining health may limit one's ability to engage in goals central to one's purpose, causing many to feel helpless and directionless. This may be particularly true for ailments with a sudden onset or those leading to disability. For example, one study of longitudinal changes following stroke onset observed declines in sense of purpose over time relative to pre-stroke purpose levels, with diminished physical and cognitive functioning predicting a lower sense of purpose (Lewis et al., 2020). However, this was not the case for individuals who had suffered a stroke several years prior to baseline, suggesting that after a period of time some patients return to relatively stable levels of purposefulness. Though events such as retirement or the onset of a health condition may disrupt past roles contributing to one's sense of purpose, older individuals may adapt to derive purpose from other pursuits.

In the face of accumulating age-related losses, individuals may engage in compensatory strategies to optimize their functioning and continue to pursue similar goals (Baltes et al., 1999). Recent research following adults around the transition into retirement found that frequent engagement in a number of physical, social, cognitive, and prosocial leisure activities mitigated against decline in purposefulness over an eight-year span (Lewis & Hill, 2020). Further, the benefits of leisure activity engagement were more pronounced among newly retired individuals, suggesting that living an engaged lifestyle may help individuals compensate for loss of roles in other areas of life. Similarly, older adults may rely on social support to pursue purposeful aims despite accruing role losses. The Pinquart (2002) meta-analysis found that social factors such as social network size and relationship quality were among the strongest predictors of sense of purpose in middle-to-older adulthood. In addition, longitudinal research in individuals around the transition into older adulthood has found that perceived social support from one's spouse, children, and friends helps to buffer against decline in purpose over an eight-year period (Weston et al., 2020). As such, though several studies have observed age-associated changes in sense of purpose, not all individuals are destined to decline in purposefulness as they age. Factors such as activity engagement and social support might help individuals preserve sense of purpose, allowing them to continue to garner benefits from purpose into older adulthood.

Purpose Promotes Desirable Health Outcomes throughout Adulthood

A myriad of research has highlighted the value of having a sense of purpose in life in fostering positive health outcomes in middle and older adulthood. Purpose is associated with reduced risk of physical disability (Boyle, Buchman, & Bennett, 2010), cardiovascular conditions such as stroke and myocardial infarction (E. S. Kim, Sun, Park, Kubzansky, et al., 2013; E. S. Kim, Sun, Park, & Peterson, 2013), Alzheimer's disease and mild cognitive impairment (Boyle, Buchman, Barnes, et al., 2010; Boyle et al., 2012), and mortality (R. Cohen et al., 2016; Hill & Turiano, 2014). Another recent study showed that purpose in life is associated with lower levels of glycosylated hemoglobin, a marker of long-term glucose regulation associated with elevated risk for Type-II diabetes, cardiovascular disease, and mortality (Boylan et al., 2017). One proposed mechanism for the association between sense of purpose in life and positive health outcomes is that purposeful individuals may be more likely to pursue health-protective behaviors. For instance, individuals higher in sense of purpose report more frequent engagement in moderate and vigorous physical activities (Hill et al., 2019; Holahan et al., 2008). This research is supported by recent findings linking higher sense of purpose with accelerometer-measured physical activity and general movement throughout the day (Hooker & Masters, 2016). Similar effects have also been observed for vegetable intake, sleep quality, and dental care (Hill et al., 2019; E. S. Kim et al., 2015, 2020). Purpose also appears to predict health behaviors in the context of health care utilization and treatment adherence. Purposeful individuals are more likely to utilize preventative medical screenings such as cholesterol tests, mammograms, pap smears, and prostate exams (E. S. Kim et al., 2014). Together, these findings point to purposeful adults taking a more active approach to their health through several health-promoting behaviors.

Another avenue of research involves the association of sense of purpose with coping and physiological reactivity to stressful experiences. Several studies have found that individuals higher in purpose report more positive reactions in response to stressors, including fewer depressive symptoms and less engagement in avoidant coping strategies (Wang et al., 2007). Additional findings have documented a relationship between sense of purpose in life and more objective measures of stress response. For example, one study showed that purposeful individuals experience reduced heart rate variability after being presented with a stress-inducing video, with those higher in purpose reporting less anxiety and a more rapid return to resting heart rate (Ishida & Okada, 2006). A related study examined emotion recovery in adults presented with negative picture stimuli through eye blink response, a measure sensitive to emotional state in response to stressors (Schaefer et al., 2013). Similar to the previous findings, those higher in sense of purpose exhibited better emotional recovery after viewing the negative stimulus. Moreover, those higher in purpose have shown to have consistently lower salivary levels of the stress hormone cortisol throughout the day (Ryff et al., 2006). Taken together, these findings suggest a healthier stress response profile: when stressors are no longer present, purposeful individuals are able to quickly reduce autonomic activation and return to a resting state.

Extending beyond health behaviors and stress reactivity, sense of purpose is associated with healthier biological risk profiles assessed via several inflammatory and functional biomarkers. Sense of purpose is related to a healthier cardiovascular risk profile, including lower levels of inflammatory cytokines, higher levels of high-density lipoprotein ("good cholesterol"), and down-regulation of pro-inflammatory genes (Fredrickson et al., 2015; Ryff et al., 2006; Zilioli et al., 2015). Additionally, individuals reporting a higher sense of purpose have been found to have significantly lower levels of soluble interleukin-6 receptors, a cytokine receptor which serves to amplify the inflammatory response (Friedman et al., 2007). One study by Zilioli and colleagues (2015) showed that sense of purpose predicted reduced allostatic load—a composite measure of several biomarkers representing functioning across a number of physiological systems. This index included markers of lipid metabolism such as body mass index and cholesterol levels, inflammatory cytokines such as interleukin-6 (IL-6) and C-reactive protein, and parasympathetic nervous system activity. Therefore, the finding of decreased allostatic load in purposeful adults reflects reduced physiological strain on immune, cardiovascular, and other bodily systems, suggesting that these individuals may be less prone to diseases resulting from chronic wear on these systems. Beyond these biomarkers, purpose also is longitudinally related to better grip strength and faster walking speed (E. S. Kim et al., 2017), two functional biomarkers known to predict cognitive change and dementia risk in late life (Cui et al., 2021; MacDonald et al., 2017).

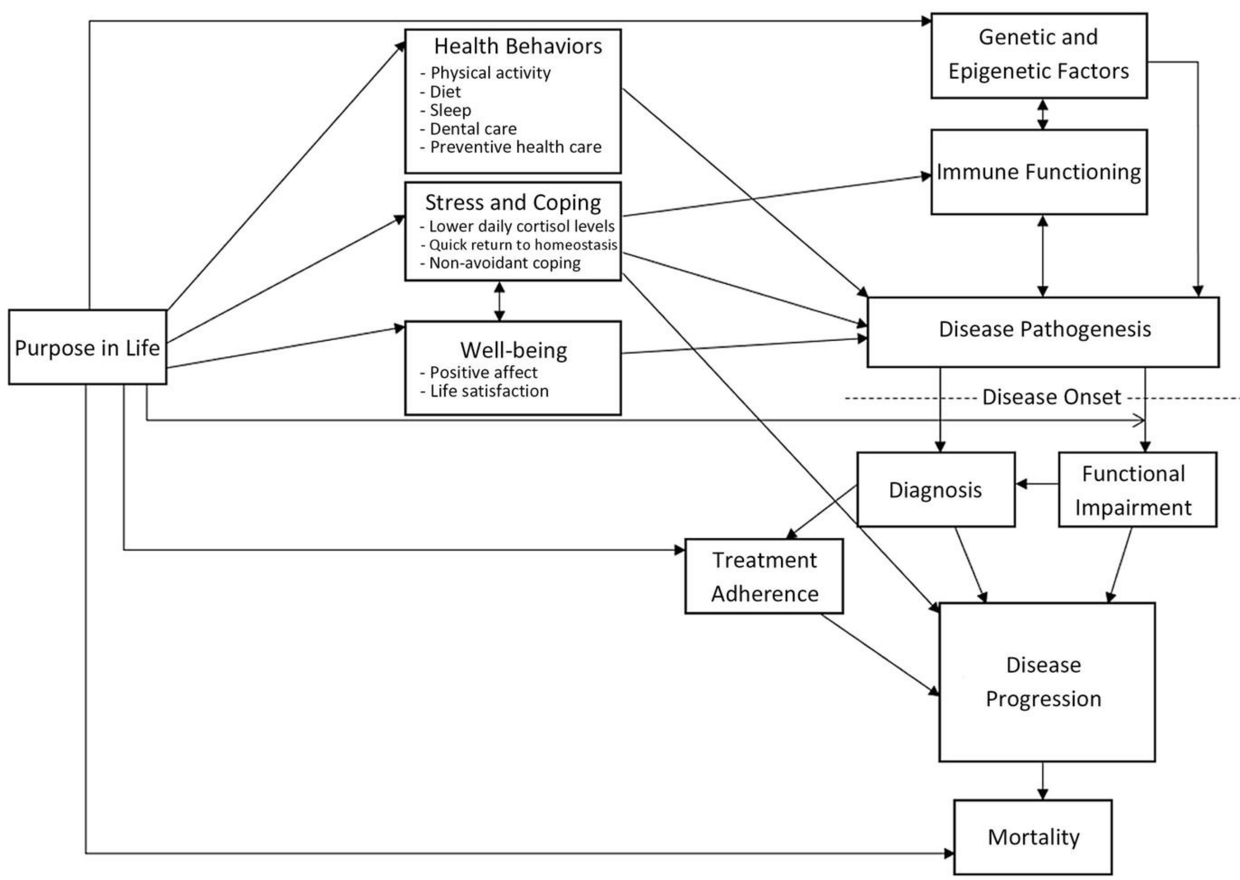
Further underscoring its benefits for adult development, a growing literature has linked purpose in life with greater cognitive health. Middle-aged and older adults reporting a higher sense of purpose perform better on several cognitive assessments including measures of executive functioning, memory, and processing speed (Lewis et al., 2017; Windsor et al., 2015). A number of potential mechanisms may account for these between-person differences in cognitive functioning. Higher sense of purpose is moderately associated with education attainment and socioeconomic factors that may support cognitive ability (Hill, Turiano, et al., 2016; Pinquart, 2002). Further, purposeful individuals may benefit from increased engagement in complex cognitive tasks associated with purpose-driven goals, leading to improved functioning through cognitive enrichment (Hertzog et al., 2008).

Considering non-normative cognitive development, prospective studies have found that more purposeful individuals have a reduced risk for developing mild cognitive impairment, Alzheimer's Disease, and other forms of dementia (Boyle, Buchman, Barnes, et al., 2010; Boyle et al., 2012). Sense of purpose may reduce risk for cognitive impairment by contributing to the cognitive reserve capacity of older adults. Cognitive reserve reflects the brain's ability to compensate for pathological changes such as brain injury or neurodegeneration, allowing some individuals to maintain cognitive functions even when widespread pathology is present (Stern, 2002). Research by Boyle and colleagues (2012) examined longitudinal changes in sense of purpose and cognitive functioning in older adults who also underwent brain autopsy upon death. They found that even after adjusting for markers of reserve such as education, purpose in life moderated the association between Alzheimer's pathology (amyloid plaques and neurofibrillary tangles) and cognition. In other words, more purposeful individuals exhibited higher cognitive functioning even when they displayed the neurological hallmarks of the disease. Though it is not clear why purpose is associated with cognitive reserve, the authors suggest that having a strong sense of purpose may promote goal pursuit and engagement in mentally stimulating activities.

In sum, purpose in life appears to contribute to improved health outcomes across multiple domains, implying that purpose works through a multitude of physical, psychological, and behavioral influences to promote health (see Fig. 1.1). Moreover, purpose has been shown to predict positive health outcomes even after adjusting for factors such as personality, psychological well-being, and demographic factors (e.g., Boyle et al., 2010; Hill & Turiano, 2014). From adolescence to older adulthood, purpose predicts desirable outcomes for those who have it. That said, there are still many opportunities to both understand the how and why of purpose.

Figure 1.1

Theoretical and Empirical Foundations for the Role of Purpose on Physical, Psychological, and Behavioral Outcomes



The Present Research

The research highlighted above provides compelling evidence that sense of purpose in life represents a valuable asset for positive aging across the adult lifespan—predicting better cognitive functioning, physical health, and improved longevity. The current dissertation aims to clarify associations between sense of purpose in life and cognitive functioning in older adulthood, as well as the biological and behavioural factors that may underlie this relationship. This work uses multi-study replications of large longitudinal datasets, as well as intensive measurement design to examine short-term (e.g., within-day, day-to-day) and long-term (years) associations between sense of purpose and markers of cognition and health.

1) Sense of Purpose and Transitions across Cognitive States and Death – The first project employs data from two large longitudinal datasets – the Rush Memory and Aging Project (MAP) and the Health and Retirement Study (HRS) – to examine state shifts in cognitive impairment. Multistate survival modeling tested whether sense of purpose predicts risk of transitioning between cognitive states (normal cognition, MCI, & dementia) as well as risk of death across follow-up periods of 12 (HRS) and 19 years (MAP). Results from these models were used to estimate life expectancies, providing insight into extent to which having a strong sense of purpose may help to delay onset of cognitive impairment and extend the lifespan.

2) **Longitudinal Associations between Sense of Purpose in Life and Allostatic Load -** Project 2 examines longitudinal associations between sense of purpose in life and allostatic load in two nationally representative samples of American (Health and Retirement Study; HRS) and English (English Longitudinal Study of Ageing; ELSA) adults over age 50. Blood-based biomarkers of cardiovascular, metabolic, immune, and renal function, as well as anthropometric and physical markers such a lung function were used to compute overall scores representing allostatic burden. Population-weighted multilevel modeling examined prospective associations between sense of purpose and allostatic load across a follow-up period of up to 8 and 12 years in the HRS and ELSA samples, respectively.

3) **Within-Day Dynamics of Sense of Purpose in Life with Cognition and Health Behaviours -** Project 3 investigated daily variations in sense of purpose and associations with

daily cognitive performance using an ecological momentary assessment design. Community-residing healthy adults (N=64; M_{age}=70.58, SD=3.5; 77% female) completed a battery of brief cognitive tasks four times per day for 14 days, as well as surveys of stress, health behaviour engagement, and well-being. Multilevel models examined within- and between-person associations between end of day sense of purpose ratings and performance on five indices of cognitive functioning.

Chapter 2 – Project 1

Sense of Purpose and Risk and Timing of Transitions across Cognitive States and Death

Abstract

A majority of research on cognitive resilience has focused on risk for impairment with less research evaluating factors linked to the potential for cognitive improvement following impairment. Sense of purpose has been shown to be associated with greater physical activity, more supportive social ties, and greater intellectual activity, and may be valuable for mitigating cognitive impairment both before and following its onset. Multistate survival modeling was used to evaluate the role of sense of purpose on transitions across cognitive states and death in two large longitudinal datasets – the Rush Memory and Aging Project (MAP) and the Health and Retirement Study (HRS). More purposeful older adults were found to have lower prospective risk of developing mild cognitive impairment (and equivalent classification in HRS), later onset of impairment, and increased likelihood of improvement in cognitive functioning following MCI classification. These results were replicated across both longitudinal studies with disparate samples and measurement procedures and were consistent with previous research identifying sense of purpose in life as a contributor to cognitive reserve and resilience. Although the present findings did not account for level of neuropathological burden, these results support the notion that having a sense of purpose may promote resilience to neurological challenges by extending the cognitive healthspan—the period in which individuals live in a cognitively healthy state free of impairment.

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*The author of the current dissertation was solely responsible for the study idea, design, and data analyses. NAL and PLH contributed equally to the writing. DAB was responsible for data collection.

Introduction

Central to the goal of mitigating non-normative cognitive decline is understanding the factors that may promote cognitive resilience. Although cognitive resilience has been defined in various ways (Stern et al., 2019), work has centered on identifying risk factors for cognitive impairment and dementia. On this front, research has demonstrated the importance of having a sense of purpose, defined as a perception one has personal goals that motivate meaningful life engagement and a sense of direction (Ryff, 1989). Past studies show sense of purpose is associated with better performance on cognitive tasks (Lewis et al., 2017; Windsor et al., 2015), and work with a subset of the current sample found it predicted reduced risk for future mild cognitive impairment (MCI) and dementia (Boyle, Buchman, Barnes, et al., 2010; Boyle et al., 2012). However, with most work focused on risk for impairment, less research has considered factors linked to the potential for cognitive improvement following impairment.

Some evidence comes from reviews of healthy cognitive aging, which have suggested that similar factors may contribute to both primary and secondary prevention of cognitive impairment (Smith, 2016), including physical activity, social relationships, and intellectual engagement. If true, sense of purpose may be valuable for mitigating cognitive impairment both before and following its onset. Living a purposeful life is thought to promote greater life engagement (Scheier et al., 2006) and necessitate working with and influencing others (Damon et al., 2003). Likewise, during adulthood, another important consideration is that sense of purpose may improve physical health, which in turn would hold downstream consequences for the development of cognitive impairment. Indeed, work consistently shows the construct is predictive of reduced risk for major health outcomes (R. Cohen et al., 2016; Zilioli et al., 2015). It is particularly noteworthy that sense of purpose has been implicated in promoting cardiovascular health (Kim et al., 2020), given its influence on risk for further decline following impairment (Langa & Levine, 2014). As such, sense of purpose appears to impart benefits along multiple fronts that would be expected to help individuals with impairment; however, it is critical to note these efforts typically are described as secondary prevention insofar that they may help stem declines or reduce symptoms, rather than necessarily turn the tide and return to an unimpaired state.

That said, research has demonstrated it is far from that easy in developing efforts to reduce mild cognitive impairment. Reviews of pharmacological interventions show limited evidence that these consistently work (Cooper et al., 2013; Langa & Levine, 2014; Winblad et al., 2004). Although recommendations commonly include health behaviours like physical activity (Law et al., 2020) when discussing symptom reduction, there are few randomized clinical trials testing their efficacy for reversing cognitive impairment. Finding effective treatments for MCI also is hindered by the heterogeneity of presentation for MCI (Winblad et al., 2004), as well as the debates surrounding what treatment even means in this case (Gaughier & Touchon, 2004; Peterson & Morris, 2005). Given these difficulties, it is unclear whether sense of purpose will predict progression from MCI, and evidence toward this end would provide a valuable advance in the midst of limited research on such progression factors.

The current study sought to test this claim given evidence that MCI status can fluctuate during adulthood (Robitaille et al., 2018). Toward this end, we employed data from two large longitudinal datasets – the Rush Memory and Aging Project (MAP) and the Health and Retirement Study (HRS) – to examine state shifts in cognitive impairment. By considering both datasets together, we gain a unique opportunity for a conceptual replication, wherein MAP provides clinical diagnoses and HRS provides measures allowing for an empirical categorization of MCI. The MAP data was previously employed in investigations of sense of purpose predicting non-normative cognitive decline (Boyle et al., 2010; 2012), and the HRS has been utilized for showing the associations between sense of purpose and cognitive functioning (Kim et al., 2019; Sutin et al., 2021). Both also have been employed for demonstrating the association between sense of purpose and mortality risk (Boyle et al., 2009). However, none of these studies have examined the role of sense of purpose in predicting progression from an impaired status, or combined the two datasets in an effort to compare clinical and non-clinical measures of MCI.

Based on that previous work, we expected to demonstrate again that sense of purpose predicts reduced risk for non-normative cognitive decline and ultimately mortality. Moreover, we sought to extend those findings to consider whether sense of purpose predicted transitions after receiving MCI classification, both in the form of progressions into dementia or even death, as well as reversions back to a non-impaired state. A central contribution of the current study is the ability to model progressions and regressions across these distinct states (intact, impairment, dementia, and mortality) in a single framework, for which we utilize multistate survival modeling (MSM). Understanding whether sense of purpose influences risk of transitioning in either direction is essential, given the clear personal and economic value of delaying onset of Alzheimer's Disease (Zissimopoulos et al., 2015), paired with evidence that sense of purpose is malleable in older adulthood (Hill & Weston, 2019) and susceptible to intervention (Friedman et al., 2017).

Methods

Participants and Procedures

Participants were from the Memory and Aging Project (Bennett et al., 2018) and the Health and Retirement Study (Sonnega et al., 2014). MAP is a cohort study of older adults (53-

100 years at baseline) recruited from retirement communities, subsidized senior housing facilities, and church groups in the greater Chicago metropolitan area. Participant recruitment, which began in 1997, includes rolling admission of new participants. Upon study enrollment, participants agree to complete annual clinical assessments until death. Assessments of sense of purpose in life were added in 2001, which is treated as the baseline wave in the present study for MAP participants enrolled before this date. The HRS is a nationally representative longitudinal study of American adults over the age of 50 and their spouses. Beginning in 1992, HRS participants are assessed every two years on topics relating to health, income, cognition, and healthcare utilization. The 2006 wave represents the baseline for HRS participants in the current study, corresponding to the introduction of the HRS psychosocial questionnaire and the first assessment of sense of purpose in life.

Participants were included in the present study if they completed the sense of purpose in life assessment at the baseline measurement for the respective samples and had available cognitive status data from two or more measurement occasions. Based on this selection criteria, the current analysis includes data from 1821 MAP participants assessed between 2001 and 2020, with an average follow-up of 7.27 years. Given the large number of younger and middle-aged adult participants in the HRS, participants from this sample were included if they were aged 60 or older at baseline, resulting in 10,542 participants followed between 2006 and 2018, with an average follow-up period of 10.48 years.

Measures

Assessment of Cognitive Status

All MAP participants completed a structured annual clinical evaluation including an extensive neuropsychological and cognitive battery assessing performance in five cognitive domains (episodic memory, working memory, semantic memory, perceptual orientation, and perceptual speed). A computer-based decision tree scored cognitive tests, and a rating of severity of impairment was computed for each cognitive domain. A neuropsychologist, blind to participant demographics, reviewed the computer generated impairment rating and other clinical information to render a clinical judgement of the presence and degree of cognitive impairment. Following this, another clinician (i.e., a neurologist, geriatrician, or geriatric nurse practitioner) reviewed the available data and examined the participant to make a final status classification of non-impaired, MCI or dementia.

Clinical diagnosis of dementia and Alzheimer's disease in MAP is based on criteria of the joint working groups of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's disease and Related Disorders Association (NINCDS/ADRDA). Specifically, Alzheimer's disease is diagnosed if there is evidence of meaningful decline in cognitive functioning relative to previous levels, with impairment in memory and at least one other domain. MCI is diagnosed when the participant is deemed to have cognitive impairment based on neuropsychological screening but does not meet other dementia criteria according to the supervising clinician. Participants are classified as having no cognitive impairment if they fail to meet criteria for MCI or dementia. Detailed description of the clinical diagnosis procedures in MAP are available elsewhere (Bennett et al., 2006).

Cognitive functioning in the HRS was assessed through a modified version of the Telephone Interview for Cognitive Status (TICS; Brandt et al., 1988). Tests included 10 word immediate and delayed recall, serial 7s subtraction test of working memory, backward counting test of attention and processing speed, object naming, tests of orientation to the date and current US president. Composite scores using these items create a measure of cognitive functioning ranging from 0 to 27. Based on these cognitive measures and proxy reports from close family members of respondents, HRS participants were classified into three categories at each wave: normal cognition, Cognitive Impairment but No Dementia (CIND), and dementia. These categories were derived from Langa-Weir classifications, which have been validated in the HRS sample and found to reliably predict clinical diagnosis of cognitive impairment and dementia (E. M. Crimmins et al., 2011).

Details of the HRS cognitive classification procedure are outline elsewhere (Langa et al., 2020). In brief, a subset of HRS participants deemed at risk for cognitive decline were selected for a detailed clinical and neuropsychological evaluation, including classification by a clinician into the three categories above. Equipercentile equating was used to derive cut-off points in the TICS cognitive battery that corresponded best to the three clinical categories. Scores ranging from 12 to 27 for normal cognition, seven to 11 for CIND, and zero to six for dementia were found to have the optimal alignment with the clinical categories. Proxy interviews, typically with a spouse or close family member, were conducted on occasions when HRS participants were unable to complete some or all of the survey independently. Proxy classification of cognition was based on proxy assessment of respondent's memory, reasons for being unable to complete the cognitive battery, impairment in instrumental activities of daily living (IADLs), and the interviewer's assessment of respondent's cognition. Classifications based on cognitive cut-offs and proxy interviews were used for the current study.

Sense of Purpose in Life

Both samples utilized the purpose in life subscale measure derived from the Ryff Psychological Wellbeing Scale (Ryff, 1989; Ryff & Keyes, 1995) to assess sense of purpose. In MAP, participants rated their level of agreement on a 5-point scale (1 = strongly disagree, 5 =

strongly agree) with 10 items such as "I am an active person in carrying out the plans I set for myself" and "some people wander aimlessly through life, but I am not one of them". The mean of these ratings was computed to create a sense of purpose in life score for each participant ranging from 1 to 5. Participants in the HRS completed a 7-item version of the Ryff measure, with scores ranging from 1 (strongly disagree) to 6 (strongly agree). Higher scores in both studies represent greater perceptions of sense of purpose in life.

Covariates

Models also adjust for age (centered on the baseline mean age), sex, education (centered on 12 years, equivalent to high school education in the United States), and baseline number of depressive symptoms on the Center for Epidemiologic Studies Depression Scale (Radloff, 1977). The MAP model also includes apolipoprotein (APOE) ε4 genotype status (0 = does not carry APOE ε4 allele, 1 = carrier of one or more ε4 allele), as genetic data is available for this sample.

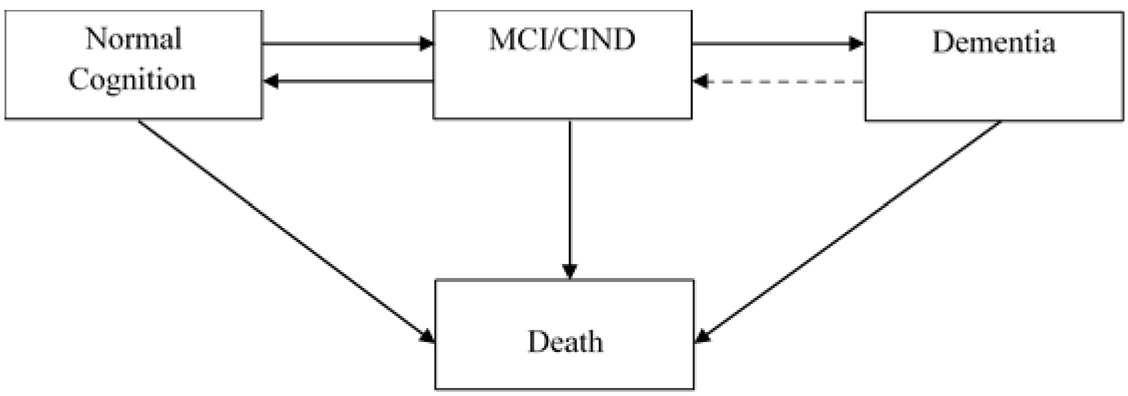
Statistical Analysis

Multi-state survival modeling (MSM) examined the effect of sense of purpose in life on risk of transitioning between cognitive states and death during the follow-up period adjusting for age, sex, education, and APOE ε4 allele status (MAP only). Relative to techniques such as Cox regression, MSM offers the advantage of simultaneously modeling multiple transitions, which may better capture progression of cognitive impairment through states of MCI and dementia, as well as the competing risk of dying before progressing to more advanced stages of impairment. A four-state model was be tested, with state 1 defined as having no cognitive impairment, state 2 as MCI/CIND, state 3 as dementia, and state 4 as death. A visual representation of this model is provided in Figure 1.1. Interval censoring was used when there was missing data between two known states and right censoring was employed for participants who were alive at the most recent data collection. All MSM analyses were performed using the MSM package for R (Jackson, 2011).

The elect package in R (van den Hout et al., 2019) was used to examine the impact of sense of purpose and other covariates on estimated overall and state-specific life expectancies. The elect package fits multinomial regression models based on the transition probabilities estimated by the MSM to compute life expectancies in each non-death state, conditional on each covariate in the model. The present study focuses primarily on estimates of overall and non-cognitively impaired life expectancies.

Figure 2.1

Four-State Survival Model Capturing Progression through Cognitive States and Death



Note. MCI = mild cognitive impairment classified by clinical diagnosis in the Memory and Aging Project sample. CIND = cognitive impairment, no dementia classified based on scores on the cognitive battery in the Health and Retirement Study sample.

Results

Baseline descriptive statistics for the present samples are displayed in Table 2.1. During the up to 19 years of follow-up in MAP, 48.65% of the sample died (n = 886, age at death = 89.79 years, SD = 6.57) and over a quarter of the sample were diagnosed with dementia. Rates of mortality and incident dementia classification were similar in the HRS sample, with approximately one fifth of the sample classified as having dementia, and less than half of the sample died during the 12-year follow-up. In both samples, right censoring was employed for participants who were alive at the most recent data collection.

Table 2.1

Characteristics of the Study Participants at Baseline

Variable	Mean (*SD*) or *n* (%)	
	MAP	HRS
Age, years	79.88 (7.71)	71.86 (7.78)
Age range	53-100	60-104
Sex, male	472 (25.92%)	4424 (41.97%)
Education, years	14.92 (3.33)	12.36 (3.14)
Race		
White	1566 (86.00%)	8940 (84.80%)
Black	105 (5.77%)	1283 (12.17%)
Other	150 (8.24%)	318 (3.02%)
Sense of purpose in life	3.67 (0.46)	4.53 (0.95)
Depressive symptoms	1.16 (1.68)	1.36 (1.87)
APOEε4 carrier	359 (19.71%)	--
Baseline cognitive status		
Normal cognition	1292 (70.95%)	8228 (78.05%)
MCI/CIND	457 (25.10%)	1835 (17.41%)
Dementia	72 (3.95%)	479 (4.54%)
Number of deaths	886 (48.65%)	4243 (40.25%)

Age at death, years	89.79 (6.57)	83.22 (8.31)
Incident dementia	471 (25.96%)	2148 (20.38%)
Age of dementia onset, years	87.74 (6.79)	80.66 (8.21)

Note: MAP = Memory and Aging Project; HRS = Health and Retirement Study; MCI = Mild Cognitive Impairment based on clinician assessment in MAP; CIND = Cognitive Impairment, No Dementia based on cognitive cut-offs in HRS.

Effects of sense of purpose in life and covariates on risk of transitioning between states in MAP are shown in Table 2.2 and in Table 2.3 for HRS. Higher sense of purpose in life at baseline was associated with lower risk of transitioning from normal cognitive functioning to MCI/CIND in both samples. This effect was slightly larger in MAP, with each 1-unit increase in sense of purpose corresponding to an 18% decreased risk of transitioning from normal cognition to MCI, compared to 7% in the HRS. Likewise, higher sense of purpose predicted increased likelihood of transitioning backwards from MCI/CIND to normal cognitive functioning in both samples.

Some notable differences were observed between samples. Sense of purpose was associated with reduced risk of progression from CIND to dementia in the HRS, but not in MAP. Further, while sense of purpose predicted reduced risk of transitioning from normal cognitive functioning to death in MAP, this association did not replicate in the HRS, though sense of purpose did predict decreased risk of death for those classified as CIND. Further, education, a key predictor of cognitive risk in older adulthood, was associated with decreased likelihood of forward progression across states of cognitive impairment in HRS. However, higher education in the HRS sample also predicted a faster rate of progression to death for individuals classified as having CIND and dementia. This pattern was not supported in MAP, with education predicting only a slight increased risk of improved cognitive function for those classified as having MCI.

Table 2.2

Hazard Ratio and 95% Confidence Intervals for the Risk of Transitions Through States of Cognitive Functioning in MAP

	Sense of Purpose	Age	Sex (male)	Education	APOEε4 allele	CESD
Transition	Hazard ratio (95% CI)					
State 1 – state 2	0.82 (0.69, 0.98)*	1.06 (1.05, 1.07)*	1.18 (1.00, 1.40)	1.02 (0.99, 1.04)	1.20 (1.02, 1.41)*	1.05 (1.00, 1.10)*
State 1 – state 4	0.62 (0.40, 0.96)*	1.10 (1.07, 1.12)*	1.71 (1.17, 2.51)*	0.95 (0.90, 1.00)	0.85 (0.53, 1.35)	1.08 (0.98, 1.19)
State 2 – state 1	1.56 (1.25, 1.94)*	0.97 (0.96, 0.98)*	0.84 (0.69, 1.03)	1.03 (1.00, 1.07)*	0.59 (0.47, 0.73)*	0.97 (0.92, 1.03)
State 2 – state 3	0.92 (0.72, 1.17)	1.06 (1.05, 1.08)*	1.06 (0.85, 1.34)	0.98 (0.95, 1.01)	1.48 (1.20, 1.82)*	1.02 (0.96, 1.08)
State 2 – state 4	1.88 (0.77, 4.54)	1.08 (1.02, 1.14)*	1.31 (0.65, 2.61)	1.01 (0.91, 1.13)	0.50 (0.18, 1.35)	1.10 (0.93, 1.31)
State 3 – state 4	1.03 (0.80, 1.32)	1.06 (1.04, 1.08)*	1.68 (1.32, 2.14)*	0.97 (0.94, 1.01)	0.90 (0.71, 1.14)	1.05 (0.99, 1.12)

Note: CESD = Center for Epidemiologic Studies Depression Scale.

Table 2.3

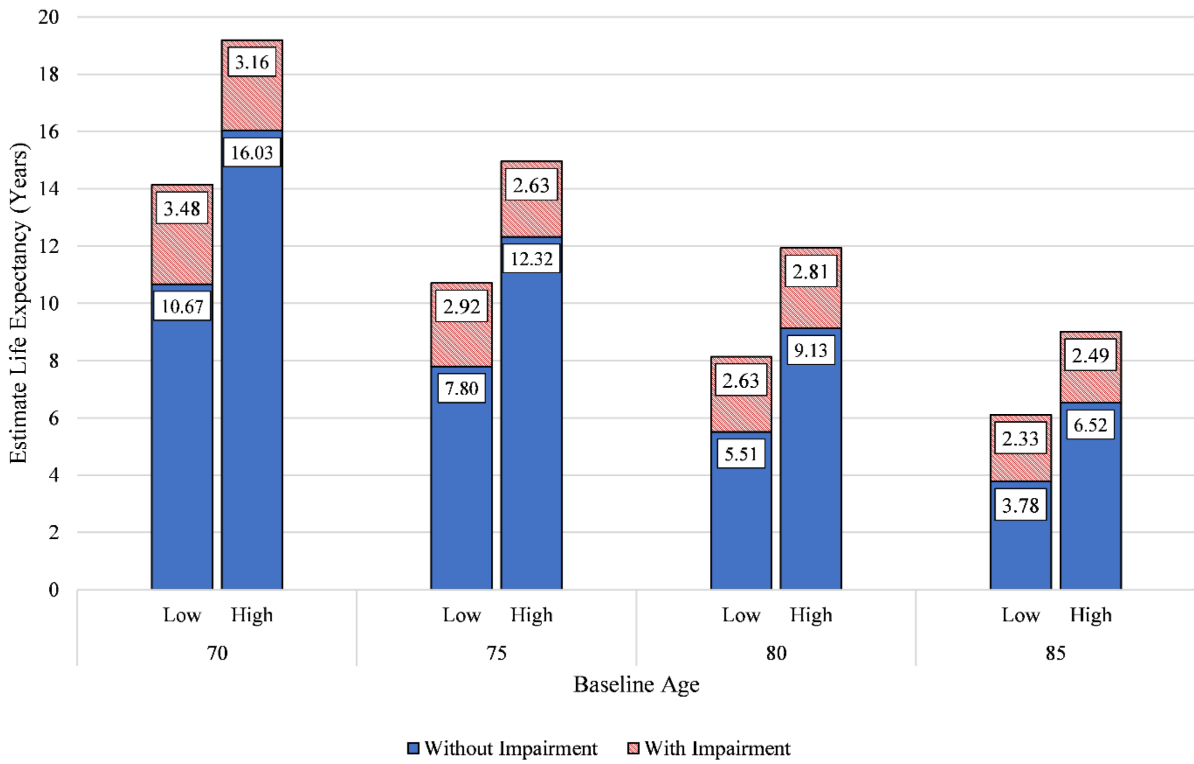
Hazard Ratio and 95% Confidence Intervals for the Risk of Transitions Through States of Cognitive Functioning in HRS

	Sense of Purpose	Age	Sex (male)	Education	CESD
Transition	Hazard ratio (95% CI)				
State 1 – state 2	0.93 (0.90, 0.97)*	1.05 (1.05, 1.05)*	0.82 (0.77, 0.87)*	0.88 (0.87, 0.89)*	1.09 (1.07, 1.11)*
State 1 – state 4	0.95 (0.86, 1.04)	1.11 (1.10, 1.12)*	0.63 (0.53, 0.75)*	0.96 (0.94, 0.99)*	1.09 (1.04, 1.14)*
State 2 – state 1	1.09 (1.05, 1.14)*	0.97 (0.97, 0.98)*	1.03 (0.96, 1.12)	1.08 (1.06, 1.09)*	0.96 (0.94, 0.98)*
State 2 – state 3	0.89 (0.85, 0.94)*	1.05 (1.04, 1.05)*	1.03 (0.93, 1.14)	0.96 (0.95, 0.98)*	1.05 (1.03, 1.08)*
State 2 – state 4	0.84 (0.72, 0.98)*	1.00 (0.99, 1.01)	0.77 (0.56, 1.06)	1.13 (1.08, 1.19)*	1.09 (1.03, 1.16)*
State 3 – state 4	0.95 (0.90, 1.01)	1.05 (1.04, 1.06)*	0.70 (0.62, 0.78)*	1.06 (1.04, 1.08)*	1.00 (0.97, 1.02)

From the MSM models, life expectancies were calculated for men and women aged 70 to 85 at baseline at 5-year increments. In MAP, an average 80-year-old female participant reporting a relatively high purpose in life (+1 standard deviation above the mean) with high school education, no APOE ε4 allele, and reporting no depressive symptoms was estimated to live an additional 11.93 years, with 9.13 of those years free of MCI or dementia (76.53%). However, an average female participant with the same characteristics, reporting a relatively low sense of purpose (-1 standard deviation) had a remaining life expectancy of 8.14 years, and 5.51 years of normal cognitive functioning (67.67%). Male participants showed a similar pattern, but with shorter life expectancies relative to female participants. This pattern persisted across all ages, such that higher purpose in life was consistently associated with longer cognitively healthy life expectancy (see Figure 2.2).

Figure 2.2

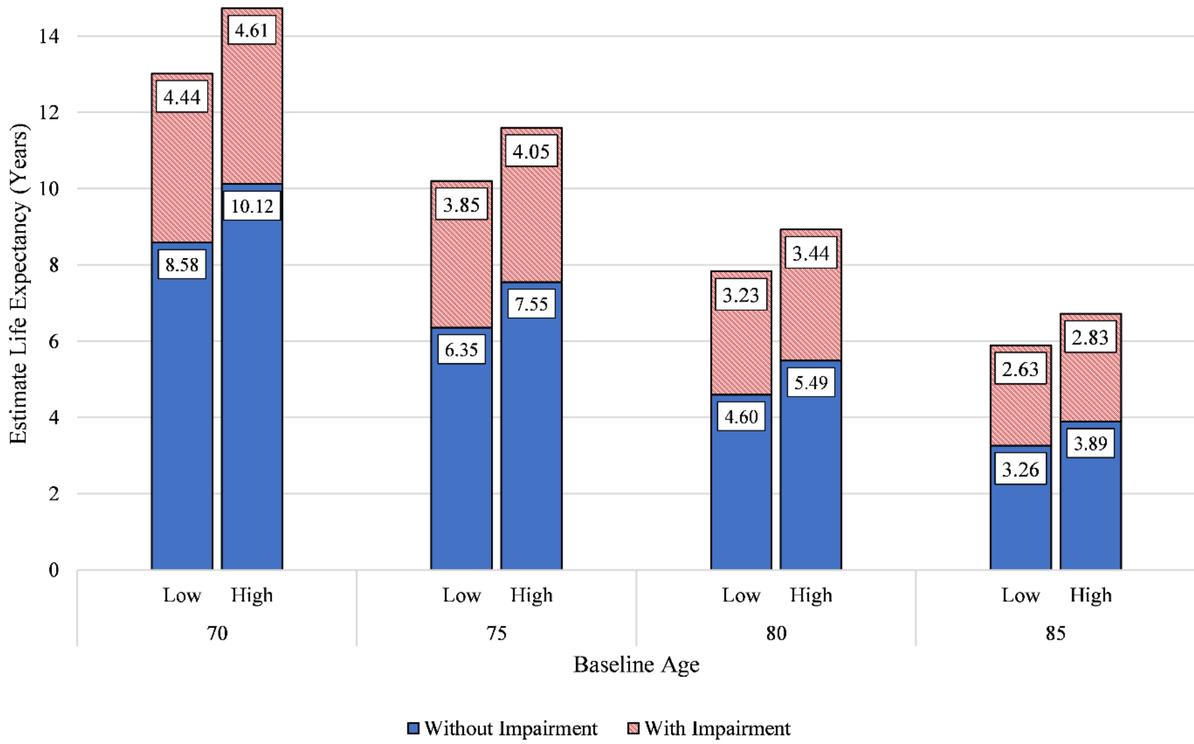
Estimated Cognitively Healthy and Impaired Life Expectancies for Female Participants with High (+1SD) and Low (-1SD) Sense of Purpose in MAP



A similar pattern was observed in the HRS sample despite differences in sample characteristics and classification of cognitive status (Figure 2.3). Participants higher in sense of purpose were expected to have consistently longer cognitive healthspan relative to those reporting lower baseline sense of purpose. For instance, a typical 70-year-old female HRS participant high in sense of purpose would be expected to live over one and a half years longer without cognitive impairment (without CIND or dementia) compared to a similar individual low in sense of purpose. Across age groups, more purposeful participants consistently spent a smaller proportion of remaining life years in a cognitively impaired state.

Figure 2.3

Estimated Cognitively Healthy and Impaired Life Expectancies for Female Participants with High (+1SD) and Low (-1SD) Sense of Purpose in HRS



Discussion

Having a sense of purpose and direction in life has been associated with manifold benefits for older adults, including reduced risk for non-normative cognitive decline (Boyle, Buchman, Barnes, et al., 2010) and early mortality (R. Cohen et al., 2016). The current study extends these past findings in three important ways. First, using a larger sample and longer timeframe, we replicated and extended past work with these datasets to show relatively consistent effects for sense of purpose on cognitive decline and mortality risk. Second, we demonstrate that these findings still hold when accounting for prominent demographic, genetic, and psychosocial predictors for cognitive impairment and early mortality. Third, using multistate modeling, we were better able to approximate when sense of purpose plays a role during the transition process from healthy cognitive status to MCI and ultimately dementia and death. Specifically, the current findings suggest that purposeful older adults are both less likely to transition from cognitively healthy to MCI, and more likely to transition back to being cognitively non-impaired after MCI diagnosis. The consistency of this story across two datasets with different measurement intervals, samples, and approaches to capturing MCI suggests the robustness of these findings. All three findings advance our understanding of the importance of sense of purpose for promoting healthy adult development, even later in the lifespan, but we focus our attention on the latter as it presents the most novel contribution.

Most notably, these findings are consistent with previous research identifying sense of purpose in life as a contributor to cognitive reserve and resilience. Past work using MAP data has found more purposeful older adults to be more resilient to dementia-related neuropathologies—experiencing better cognitive performance than expected based on level of pathologic burden (Boyle et al., 2012). Corroborating this finding, the present study found more purposeful individuals experienced a compression of cognitive morbidity typical of cognitive reserve (Scarmeas & Stern, 2003; Stern, 2002). That is, among participants who developed MCI or dementia, more purposeful individuals experienced later onset of cognitive impairment relative to those lower in sense of purpose and spent a greater proportion of their remaining life years in a cognitively healthy state. Though the present findings did not account for level of neuropathological burden, they do support the notion that having a sense of purpose may promote resilience to neurological challenges by extending the cognitive healthspan—the period in which individuals live in a cognitively healthy state free of impairment.

Interestingly, this association between sense of purpose in life and delayed progress to cognitive impairment was observed in both samples and comparable in effect size to education, a well-established marker of cognitive reserve. With no known cure for Alzheimer's disease and related dementias, delaying the onset of cognitive decline represents a key target for future dementia research. Indeed, even a modest delay in onset of one year is projected to lead to reduction of millions of persons living with dementia by 2050 and lead to savings of billions of dollars in projected annual global care costs (Brookmeyer et al., 2007; Zissimopoulos et al., 2015). Supporting older adult sense of purpose in life, along with other predictors of cognitive reserve such as cognitive enrichment (Stine-Morrow et al., 2014), therefore represents an important target for mitigating societal impacts of cognitive impairment and dementia.

Although work has demonstrated that sense of purpose cross-sectionally (Lewis et al., 2017) and longitudinally (Dewitte et al., 2021; Windsor et al., 2015) predicts cognitive functioning in adulthood, the current findings provide the first evidence that it may increase the possibility of transitioning out of MCI back to a cognitively non-impaired, healthy state. Moreover, these findings were apparent even when accounting for depressive symptoms, suggesting they are unlikely to result simply from psychological well-being, and even occurred when accounting for genetic predispositions for cognitive decline in the MAP sample. At least three possible reasons may account for this positive shift out of a cognitively impaired state. First, sense of purpose has been linked longitudinally to being less physically inactive and maintaining a better body mass index during older adulthood (E. S. Kim et al., 2020). Couched in World Health Organization recommendations for physical activity interventions to reduce risk for non-normative cognitive decline (World Health Organization, 2019), it may be the case that purposeful older adults are more likely to maintain physical fitness and in turn avoid further non-normative declines in cognitive functioning. Second, sense of purpose has been linked to better healthcare utilization by older adults (E. S. Kim et al., 2014), which in turn may lead to a better understanding of and adherence to the recommended treatment for MCI. Third, sense of purpose in older adulthood appears closely intertwined with greater social support (Weston et al., 2020);

as such, purposeful older adults have greater opportunities to utilize their support base to help them return to a cognitively healthier state. For instance, through increased social activity or assistance with recommendations provided by the clinicians who initially diagnosed them with cognitive impairment. Future research is needed to compare different explanations, though given the multifaceted nature of leading a purposeful life, it is likely that these prove supplemental rather than exclusive pathways to cognitive resilience.

Although the findings were very consistent across studies, two differences merit attention. First, only in the HRS sample, sense of purpose also predicted a reduced likelihood for individuals to move from dementia to mortality. Although the effect was only significant in HRS, the hazard ratios were markedly similar for the transition from MCI to dementia; therefore the transition from dementia to mortality was the only clear discrepancy between the samples. Second, the effect sizes tended to be larger in the MAP than HRS samples across most MSM parameters, although with wider confidence intervals due to the smaller sample size. Both differences may result from the differences in how cognitive impairment and dementia were captured. Using clinical assessments and thresholds, the MAP likely captured distinctions in cognitive status that were of a qualitatively greater difference, compared to the criteria employed in HRS. In turn, this may lead to greater effect sizes due to the stronger distinctions between states, as well as the potential for more individuals to be counted in the two impaired states in the HRS. Past research has shown that sense of purpose holds differential associations depending on the cognitive functioning measure (Dewitte et al., 2021; Lewis et al., 2017). As such, our findings coincide with this work in calling for continued research on which cognitive metrics are more associated with sense of purpose, which also should help uncover the underpinnings and mechanisms linking purpose to cognitive health.

A few limitations of the current work merit attention for future research. First, the current sample was fairly homogenous with respect to race, and all came from the same geographic region. Second, additional details on what information participants received following the clinical evaluation would be valuable, in order to consider whether sense of purpose promoted cognitive resilience through greater adherence to either clinician or outside recommendations. Sense of purpose has been linked with reduced conflict-related neural processing during health decision-making (Kang et al., 2019); thus, future research should consider whether sense of purpose predicts how individuals interpret information regarding their potential cognitive impairment, in order to better tailor secondary prevention strategies. As such, the current study presents multiple opportunities to expand upon the current demonstrations that sense of purpose may yield greater expectancy both for one’s lifespan in general and the amount of years free of cognitive impairment.

Chapter 3 – Project 2

Longitudinal Associations between Sense of Purpose in Life and Allostatic Load

Abstract

Sense of purpose in life has been linked with better physical health, longevity, and reduced risk for disability and dementia, but the mechanisms linking purposefulness with diverse health outcomes are unclear. Chronic activation and dysregulation of neural, immune, and other bodily systems, known as allostatic load, may contribute to these underlying mechanisms. Specifically, sense of purpose may promote better physiological regulation in response to stressors and health challenges, leading to lower allostatic burden and disease risk over time. Data from the nationally representative US Health and Retirement Study (HRS) and English Longitudinal Study on Ageing (ELSA) (Total N=6461; Mean Age=67.24, *SD*=10.68, 59.08% female) were used to examine associations between sense of purpose and repeated assessments of allostatic load across 8 and 12 years of follow-up. Population-weighted multilevel models revealed that sense of purpose in life was associated with lower overall levels of allostatic load in HRS, but not in ELSA after adjusting for relevant covariates. Sense of purpose in life did not predict rate of change in allostatic load in either sample. This investigation provides insight into potential biological mechanisms linking sense of purpose with better health outcomes through individual biomarkers and multi-system physiological dysregulation.

Note: The following chapter represents original work not previously published in any form.

Introduction

Having a sense of purpose in life represents an important resource for healthy aging across the adult lifespan. Sense of purpose, characterized by the perception that one's life has direction and meaning (Ryff, 1989), is associated with resilience to disease and disability outcomes across a range of bodily systems. A sense of purpose is associated with reduced risk for cardiovascular events (E. S. Kim, Sun, Park, Kubzansky, et al., 2013; E. S. Kim, Sun, Park, & Peterson, 2013; Yu et al., 2015), functional disability and hospitalization (Boyle, Buchman, & Bennett, 2010; Wilson et al., 2018), auditory impairment (Sutin, Luchetti, Aschwanden, Stephan, et al., 2022), cognitive impairment and dementia (Boyle, Buchman, Barnes, et al., 2010), as well as increased longevity (R. Cohen et al., 2016). Despite the apparent connection between living a purposeful life and these diverse health outcomes, little is known about the mechanisms linking sense of purpose with long-term health and functioning. Understanding the biological underpinnings concerning sense of purpose and salubrious outcomes could further reinforce the potential utility of purpose interventions as a non-pharmacological approach to supporting healthy aging.

One mechanism is that more purposeful individuals may be better equipped for adaptive physiological regulation in response to stressors and health challenges. In times of stress, having a central, motivating life aim may buffer psychological distress related to feelings of lack of control and promote more efficient resource allocation to respond to the stressor (McKnight & Kashdan, 2009). Empirical findings seem to support this notion. After mobilizing physiological resources in response to an external threat or stressor, more purposeful individuals show faster recovery; quickly reducing autonomic activation and returning to a resting state. This more adaptive stress recovery response has been observed across several indicators of sympathetic nervous system activation. Following a stress response, sense of purpose predicts faster declines in heartrate variability and cortisol levels to pre-stress baseline levels (Fogelman & Canli, 2015; Ishida & Okada, 2006), as well as faster emotional recovery measured via eye blink startle response (Schaefer et al., 2013). In this manner, adults higher in sense of purpose may benefit from more efficient stress recovery, minimizing chronic activation of sympathetic responses. This is significant as chronic, prolonged activation of neural, immune, and hormonal systems involved in the stress response may lead to overstimulation and dysregulation of these systems—a state known as allostatic load (McEwen, 1998).

The term allostasis reflects an organism's ability to mobilize internal resources to maintain stability when faced with external changes (McEwen & Wingfield, 2003). Activation of systems such as the autonomic nervous system, the hypothalamic-pituitary-adrenal axis, and inflammation can promote adaptation to external challenges, but may also lead to damage if these systems are overtaxed (McEwen, 1998). The cumulative long-term effect of experiences with stressors, as well as health-damaging behaviours such as smoking or being sedentary, can lead to a cascade of dysregulation of these adaptive systems and increase risk for pathophysiology (Suvarna et al., 2020). Indeed, higher allostatic load is associated with health outcomes consistent with accelerated biological aging such as increased risk for cardiovascular disease, frailty, cognitive decline, and numerous other chronic health conditions (Guidi et al., 2021). The cumulative effects of living a purposeful life may allot individuals more resources for combatting stressful experiences and lead to pursuit of more health-congruent behaviours and lifestyle (Lewis, 2020; McKnight & Kashdan, 2009). In this way, individuals higher in sense of purpose may avoid the physiological wear and tear associated with allostatic load, leading to reduced risk of dysfunction and disease across numerous bodily systems.

Sense of Purpose in Life and Markers of Physiological Functioning

Existing research supports the notion that more purposeful individuals may be less susceptible to physiological dysregulation characteristic of allostatic load. As noted in the introductory chapter, more purposeful individuals engage more frequently in protective health behaviours. Among several behavioural correlates of sense of purpose, past research has found sense of purpose to be associated with higher levels of self-rated and objective measures of physical activity, greater adherence to physician-recommended treatment, better dietary nutrition, and frequent engagement in dental care and hygiene practices (Hill et al., 2019; Holahan et al., 2008; Kang et al., 2019; Musich et al., 2018). Further, recent longitudinal work in one of the samples used in the present study has linked sense of purpose with decreased risk of becoming physically inactive, resumption of smoking behaviour, and developing sleep problems over an eight-year period (E. S. Kim et al., 2020). These findings are critical in the context of past work showcasing the impact of lifestyle behaviours on allostasis. While health risk behaviours can increase susceptibility to allostatic load (Suvarna et al., 2020), protective health behaviours such as being physically active can help preserve functioning of hormonal, immune, and metabolic systems involved in allostasis (Gay et al., 2015).

Likely due to these behavioural outcomes, in part, having a sense of purpose in life predicts a healthier biological profile across several individual biomarkers commonly used in the construction of allostatic load indexes. For instance, individuals higher in sense of purpose in life have been found to have lower plasma concentrations of soluble interleukin-6 receptors—a receptor complex involved in the initiation of pro-inflammatory processes (Friedman et al., 2007; Ryff et al., 2004). Further support for associations between sense of purpose and inflammation come from research on the acute-phase proteins C-reactive protein (CRP) and fibrinogen—

proteins involved in the innate immune response whose secretion is triggered by pro-inflammatory cytokines. Past work has linked sense of purpose in life and related constructs with lower fibrinogen (Steptoe & Fancourt, 2019), lower circulatory CRP levels (Friedman & Ryff, 2012; Steptoe & Fancourt, 2019), and decreased likelihood of developing elevated CRP over time in men (Guimond et al., 2022). Additionally, those with higher reported sense of purpose in life may benefit from better regulation of metabolic processes, with longitudinal studies linking sense of purpose with better glucose regulation characterized by lower levels of glycated hemoglobin (Hafez et al., 2018) and reduced risk of developing unhealthy body mass index (BMI; Kim et al., 2020).

Given this growing body of evidence supporting health-protective effects of sense of purpose across numerous biomarkers, it is not surprising that research has found more purposeful individuals to have lower allostatic burden. One investigation by Zilioli and colleagues (2015) examined the association between sense of purpose in life and allostatic load at a 10-year follow-up in a large sample of American middle adults. Scores on allostatic load—comprising markers of metabolism such as glucose and cholesterol levels, inflammatory markers like C-reactive protein, cardiovascular and other biomarkers—was found to be lower at the 10-year follow-up among individuals higher in baseline sense of purpose. This finding suggests that more purposeful individuals may be less prone to diseases resulting from chronic wear on these systems. However, there remain uncertainties about the potential influence of sense of purpose in life on allostatic burden over time. First, the study by Zilioli and colleagues focused on the relationship between baseline sense of purpose and level of allostatic load at follow-up, meaning it is unclear whether sense of purpose predicts change in allostatic load across multiple measurement occasions. Second, the assessment of allostatic load at a single time point limits the ability to capture within-person dynamics including changes within individuals across time in both allostatic load and sense of purpose.

Indeed, longitudinal models suggest that markers of biological risk in middle and older adults increase on average over time, however, there remains significant within-sample heterogeneity in overall rate of change across follow-up, as well as change across individual measurement occasions (Jenkins et al., 2022). For instance, in a nearly three-year longitudinal study of older adults, over a third of the sample experienced a reduction in allostatic load at follow-up, primarily driven by decreases in hip-to-waist ratio, blood pressure, and total cholesterol (Karlamangla et al., 2006). Thus, while the typical pattern involves increasing physiological risk with advancing age, individual differences in within-person change exist and are not captured in studies of mean-level, between-person differences. Longitudinal designs including measurements of these constructs on at least three occasions are needed to utilize multilevel growth techniques that can capture interindividual differences and intraindividual change across time (Ram & Grimm, 2007). Further, many of the studies connecting sense of purpose with individual biomarkers have utilized smaller clinical samples, which may lack generalizability to the population as a whole.

Building on this need, the present study seeks to examine associations between sense of purpose in life and repeated longitudinal assessments of allostatic load in two large national panel studies. The aims of the present project are twofold: (i) to assess whether interindividual (between-person) differences in sense of purpose in life account for level and rate of change in allostatic burden across the follow-up periods, and (ii) examine the intraindividual (within-person) dynamics of sense of purpose and allostatic load across time. That is, this second aim will investigate whether within-person changes in an individual's perceived sense of purpose correspond to concurrent changes in allostatic load across measurement occasions.

Methods

Participants and Procedures

Project 2 used data from two nationally representative panel studies of US and English older adults; the Health and Retirement Study (HRS; Sonnega et al., 2014) and the English Longitudinal Study of Ageing (ELSA; Steptoe et al., 2013). The HRS is a biennial longitudinal study beginning in 1992 aimed at exploring health, aging, and retirement in American adults over the age of 50 and their spouses. Beginning in 2006, HRS data collection was expanded to include evaluations of psychosocial functioning, including assessment of sense of purpose in life, as well as measures of physical functioning and collection of blood-based biomarkers. This enhanced data collection included a randomly selected half of the sample, with the remaining half of the HRS sample assessed in 2008. Measurement of biomarkers and psychosocial function were repeated at four-year intervals. HRS data for the current project included participants with at least one measurement of sense of purpose in life and available blood sample beginning in 2006, with longitudinal data spanning to the 2016 wave—the most recent wave with available biomarker data.

Designed as a companion study to the HRS, ELSA aims to capture aging, health, finances, and attitudes of English adults over age 50. Since its inception in 2002, ELSA has collected data from participants every two years, including nurse visits in waves 2, 4, 6, and 8 (spanning 2004-2018). Nurse visits involved in-person assessment from a qualified nurse to collect data on physical functioning, anthropometrics, and blood sample collection for biomarker assessment. An optional supplemental wellbeing survey, including assessment of sense of purpose in life, was offered to ELSA participants on one occasion in the 2004 wave. Eligible ELSA participants for the present study included individuals with available sense of purpose in life and biomarker data sufficient for computation of allostatic load scores on at least one occasion beginning in the 2004 wave (baseline for the present study).

Measures

Sense of Purpose in Life

Sense of purpose in life was assessed in both samples using versions of the Ryff Psychological Well-Being Scale (Ryff, 1989). In the HRS, sense of purpose was evaluated using a seven-item version of the Ryff measure, repeated at four-year intervals beginning in 2006. Participants were asked to rate on a six-point scale, from strongly disagree (1) to strongly agree (6), their agreement with statements such as "I live life one day at a time and don't really think about the future," "I am an active person in carrying out the plans I set for myself," and "I have a sense of direction and purpose in my life." Previous work using this sample has found this scale to have good internal reliability across measurement occasions in the HRS sample (Lewis & Hill, 2020).

In ELSA, sense of purpose in life was assessed on one occasion as part of a supplement to the second wave of data collection in 2004 in which a random 10% of the sample were invited to complete an optional mail-in survey about beliefs and well-being. A total of 747 participants were selected to receive the self-completed questionnaire, of which 408 participants completed and returned by mail. This survey included an eight-item measure of sense of purpose, with participants rating their agreement with items on a seven-point scale ranging from strongly disagree to strongly agree. Items overlap directly with those in the HRS measure, with ELSA including one additional item "some people wander aimlessly through life, but I am not one of them." In both samples, negatively phrased items were reverse coded, and the mean of these items computed such that higher scores indicate a greater perception of living a purposeful life.

Allostatic Load

Allostatic load was computed as the number of biomarkers in which participants had values that fall into a clinical risk range. Biomarkers include blood-based and anthropometric markers representing functioning of cardiovascular, metabolic, inflammatory, muscular, and respiratory systems. Each biomarker measurement was scored into three categories representing low (0), moderate (0.5), and high risk (1) based on established clinical cut-off values (see Rodriquez et al., 2019). A summary of available biomarkers in HRS/ELSA and their clinical cut-off values is provided in Table 3.1. Universal clinical cut-off values are not available for grip strength and peak expiratory flow (lung function) but were established by placing participants into sex- and height-stratified tertiles, with higher tertiles representing higher performance on these tests and lower clinical risk. In other words, higher functioning tertiles were given scores of 0, and poorest functioning tertiles were assigned values of 1, corresponding to greatest risk. Scores for each of the biomarkers were summed such that higher values represent higher allostatic burden across multiple bodily systems.

Table 3.1

Clinical Risk Cut-Offs for Biomarkers Available in HRS and ELSA

System	Biomarker	Cut-off Values	HRS	ELSA
Cardiovascular	Systolic blood pressure	H: ≥ 150 mmHg, M: 120-149, L < 120	Yes	Yes
	Diastolic blood pressure	H: ≥ 90 mmHg, M: 80-89, L: < 80	Yes	Yes

Metabolic	Total cholesterol	H: ≥ 240 mg/dL, M: 200-239, L: < 200	Yes	Yes
	High density lipoprotein	H: < 40 mg/dL, M: 40-59, L: > 60	Yes	Yes
	Glycated hemoglobin	H: ≥ 6.50%, M: 5.70-6.49, L: < 5.70	Yes	Yes
	Cystatin C	H: >=1.24 mg/L, M: < 0.65, L: 0.65-1.23	Yes	No
	Triglycerides	H: >=2.30 mmol/L, M: 1.80-2.29, L:<1.8	No	Yes
	Fasting glucose	H: >= 11.1 mmol/L, M: 7.8-11, L: < 7.8	No	Yes
Inflammatory	C-reactive protein	H: > 3 mg/L, M: 1- 2.9, L: < 1	Yes	Yes
	Fibrinogen	H: >= 4.0g/L, M: < 2.0, L: 2-4 g/L	No	Yes
Anthropometric	Body mass index	H: ≥ 30 kg/m2, M: 25-29 & <18, L: 18-24	Yes	Yes
	Peak expiratory flow	Sex and height stratified (tertiles)	Yes	No
	Grip strength	Sex and height stratified (tertiles)	Yes	Yes

Note. H = high risk category (coded as 1), M = moderate risk category (coded as 0.5), L = low risk category (coded as 0). HRS = Health and Retirement Study. ELSA = English Longitudinal Study of Ageing.

Allostatic load scores were constructed from ten total biomarkers in the HRS and 11 in ELSA. Procedures for assessing physical measures in HRS and ELSA are discussed in detail elsewhere (Guyer et al., 2017). In brief, assessment for most biomarkers was harmonized across the two samples, utilizing identical or equivalent materials and procedures. Systolic and diastolic blood pressure was measured using Omron brand HEM-780 and HEM 907 automated blood pressure monitors in the HRS and ELSA, respectively. Participants were asked to sit quietly for five minutes prior to blood pressure measurement, at which time three measurements were taken in the seated position. Grip strength was measured using a Smedley spring type hand dynamometer in both studies. Several measurements were recorded for each hand, with maximum grip strength in kilograms used for allostatic load score construction. Peak expiratory flow (PEF) was recorded in the HRS as the maximum of three measurements using a Mini Wright Peak flow meter with the respondent in standing position.

Blood-derived biomarker collection differed slightly between the two samples, with HRS collecting dried blood spots and ELSA conducting whole blood draws. Dried blood spots were collected in HRS using a BD lancet and two filter paper collection cards, where the first drop that formed was wiped away to remove coagulating materials. In ELSA, nurses collected 24 mL fasting whole blood samples for respondents under age 80. Although biomarkers collected through dried blood spots often correlate highly with those from whole blood samples, they may differ in scale, leading to challenges in comparisons across collection methods (Crimmins et al., 2014). To facilitate comparisons across studies, the blood spot assays in the HRS have been scaled to match whole blood values from the related National Health and Nutrition Examination Survey, a representative cross-sectional sample with similarly aged participants.

Statistical Analyses

Population-weighted multilevel models (Raudenbush & Bryk, 2002) examined whether sense of purpose in life predicts allostatic load across the follow-up period in both analytic samples. Multilevel modeling with maximum likelihood estimation was used as it is robust to missing data issues common in longitudinal studies and it permits the examination of both within-person and between-person dynamics on change over time (Hoffman & Stawski, 2009). With the HRS sample including repeated assessment of sense of purpose over time, two different centering techniques were used to account for within- and between-person sources of variation in sense of purpose in this two-level design. At the within-person level (Level-1), sense of purpose was person-mean centered to reflect fluctuations over time in individuals' purposefulness relative to their own typical levels. This within-person effect addresses aim two of the present study, investigating whether individuals experience relative decreases in allostatic burden on occasions in which they report increases in sense of purpose in life.

At the between-person level (Level-2), sense of purpose was centered on the overall sample mean to account for consistent differences between individuals across the follow-up period. Baseline scores for sense of purpose in life in the ELSA sample were included at this between-person level. These between-person effects address aim one of the present study, providing insight into whether interindividual differences in sense of purpose predict overall level (intercepts) and rate of change (slopes) in allostatic load across time. In addition to sense of purpose in life, models adjusted for age at baseline, sex, education, race, and depressive symptoms. The following formula represents the multilevel model for the HRS sample:

Level 1 (Within-Person):

$$Allostatic\ Load_{ti} = \beta_{0i} + \beta_{1i}(Time) + \beta_{2i}(PurposeWP) + e_{ti}$$

Level 2 (Between-Person):

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Age) + \gamma_{02}(Sex) + \gamma_{03}(Education) + \gamma_{04}(Race) + \gamma_{05}(Depress) + \gamma_{06}(PurposeBP) + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + \gamma_{11}(Age) + \gamma_{12}(Sex) + \gamma_{13}(Education) + \gamma_{14}(Race) + \gamma_{15}(Depress) + \gamma_{16}(PurposeBP) + u_{1i}$$

$$\beta_{2i} = \gamma_{20} + u_{2i}$$

Population-level weighting was applied to all multilevel analyses to improve generalizability to the respective English and American adult populations and to account for selectivity in participation in biomarker collection. In the HRS and ELSA samples, participants were not included in biomarker collection if they were residing in a nursing facility, were younger than age 50 at the time of data collection or completed a proxy or phone interview. HRS biomarker weights were derived from propensity modeling predicting the probability of completing biomarker collection, adjusting for demographic and health characteristics, and post-stratification to align with population composition by age, sex, and race. Similar procedures were used in ELSA to compute sample weights and minimise bias from non-response amongst key groups and those not eligible for blood sample collection. Blood sample weights from the baseline 2004 ELSA wave were used for analyses. Comprehensive descriptions of the HRS and ELSA biomarker weighting procedures are provided elsewhere (Crimmins et al., 2013; Steptoe et al., 2013). Analyses were performed in Mplus Version 8 (Muthén & Muthén, 1998-2017).

Sensitivity Analyses

Additional models were run to evaluate whether results were impacted by allostatic load score composition. Allostatic load scores using only blood-based biomarkers were computed to test whether results were influenced by anthropometric measures or driven primarily by associations with cardiovascular, metabolic, and inflammatory systems. Allostatic load scores were constructed from the same group of biomarkers described above but excluded grip strength and peak expiratory flow. Thus, for the sensitivity analyses, the HRS and ELSA allostatic load scores were derived from eight and nine biomarkers, respectively.

Results

Demographic Characteristics and Intercorrelations

Table 3.2 provides descriptive statistics at baseline for demographic and biomarker variables in the HRS and ELSA samples. HRS participants completed an average of 2.34

biomarker assessments, resulting in an average follow-up period of 5.36 years; compared to a mean of 3.26 assessments and 9.04 follow-up years in ELSA. Tables 3.3 and 3.4 present intercorrelations between baseline sense of purpose and individual biomarkers used in the computation of allostatic load scores in HRS and ELSA, respectively. In the HRS, sense of purpose showed small correlations with most biomarkers, with the highest magnitude correlations being with the anthropometric measures of expiratory flow and grip strength as well as the metabolic markers cystatin C and glycated hemoglobin. Conversely, sense of purpose was most strongly correlated with triglyceride levels and fibrinogen in ELSA.

Table 3.2

Baseline Descriptive Statistics for the Two Samples

Variable	HRS	ELSA
N	6053	338
Age, years	66.69 (10.44)	65.72 (8.87)
Sex, female	3979 (59.08%)	182 (53.85%)
Education, years	12.66 (3.11)	--
Education, college or higher	2211 (36.53%)	117 (34.62%)
Race, Caucasian	5570 (82.70%)	335 (99.11%)
Depressive symptoms	1.41 (1.94)	1.33 (1.67)
Sense of purpose in life	4.56 (0.92)	5.31 (0.97)
Systolic BP, mmHg	130.66 (20.51)	136.22 (19.01)
Diastolic BP, mmHg	79.47 (11.69)	75.63 (10.51)
Total cholesterol, mg/dL	202.75 (42.13)	230.95 (48.77)
HDL cholesterol, mg/dL	54.74 (16.13)	58.89 (13.83)

HbA1c, %	5.83 (0.97)	5.54 (0.61)
Cystatin C, mg/L	1.10 (0.50)	--
Triglycerides, mmol/L	--	1.76 (1.04)
Fasting glucose, mmol/L	--	4.99 (0.89)
CRP, mg/L	4.56 (8.77)	3.60 (5.49)
Fibrinogen, g/L	--	3.26 (0.72)
BMI, kg/m^2	28.23 (5.78)	27.59 (4.48)
PEF, L/minute	359.77 (132.60)	--
Grip strength, kg	32.07 (11.20)	31.88 (11.11)
Allostatic load	3.18 (1.35)	3.68 (1.47)

Note. BP = Blood pressure. HDL = high density lipoprotein. HbA1c = Glycated hemoglobin. CRP = C-reactive protein. BMI = body mass index. PEF = peak expiratory flow.

Table 3.3

Baseline Zero-Order Correlations between Sense of Purpose and Biomarkers in HRS

7	8	9	10	11	12
-.13*	-.06*	-.07*	.18*	.13*	-.21*
.07*	.01	.09*	-.03*	.05*	.50*
-.09*	.00	.17*	.07*	.13*	.38*
-.11*	-.05*	-.02	.00	-.01	.09*
-.12*	-.08*	-.21*	-.13*	-.22*	-.34*
.10*	.09*	.18*	-.08*	-.07*	.36*
1	.20*	.09*	-.17*	-.17*	.40*
	1	.18*	-.11*	-.07*	.27*
		1	.09*	.12*	.38*
			1	.65*	-.32*
				1	-.20*
					1

Variable	1	2	3	4	5	6
1. Purpose	1	-.04*	.02	.05*	.09*	-.10*
2. Sys BP		1	.72*	.02	-.06*	.11*
3. Dia BP			1	.13*	-.00	.02
4. Total chol				1	.27*	-.06*
5. HDL chol					1	-.12*
6. HbA1c						1
7. Cystatin C						
8. CRP						
9. BMI						
10. PEF						
11. Grip						
12. AL						

Note. Sys BP = systolic blood pressure. Dia BP = diastolic blood pressure. Chol = cholesterol. HDL = high density lipoprotein. HbA1c = Glycated hemoglobin. CRP = C-reactive protein. BMI = body mass index. PEF = peak expiratory flow. AL = Allostatic load.

Table 3.4

Baseline Zero-Order Correlations between Sense of Purpose and Biomarkers in ELSA

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Purpose	1	-.07	.01	-.05	.07	.02	-.14*	-.03	-.12*	-.16*	-.11*	-.11*	-.16*
2. Sys BP		1	.61*	.08	-.01	.11*	.08	.10	.03	.03	.15*	-.01	.44*
3. Dia BP			1	.06	-.03	.01	.05	.07	.05	.02	.22*	.10	.39*
4. Total chol				1	.39*	-.07	.30*	-.01	.11	.15*	.04	-.14*	.28*
5. HDL chol					1	-.17*	-.33*	-.10	-.02	-.03	-.23*	-.28*	-.31*
6. HbA1c						1	.18*	.77*	.03	.07	.20*	-.04	.35*
7. Triglycerides							1	.13	.09	.08	.29*	.04	.48*
8. Glucose								1	-.05	-.13	.09	.13	.18*
9. CRP									1	.52*	.23*	-.02	.36*
10. Fibrinogen										1	.19*	-.15*	.44*
11. BMI											1	-.03	.54*
12. Grip												1	-.14*
13. AL													1

Note. Sys BP = systolic blood pressure. Dia BP = diastolic blood pressure. Chol = cholesterol. HDL = high density lipoprotein. HbA1c = Glycated hemoglobin. CRP = C-reactive protein. BMI = body mass index. PEF = peak expiratory flow. AL = Allostatic load.

Multilevel Models Predicting Longitudinal Change in Allostatic Load

Prior to the main analyses, two-level intercept-only models were run to compute intraclass correlation coefficients (ICC)—indicating the amount of variance in allostatic load at each level of the models. These models yielded ICC values of 0.61 in HRS and 0.57 in ELSA; indicating that around 61% and 57% of the variance in allostatic load occurred between persons, with the remaining 39% and 43% representing within-person changes in allostatic load. In other words, while persistent between-person differences accounted for most of the variability in level of allostatic burden, participants did experience fluctuations in allostatic load scores across the longitudinal follow-up period.

Results of the multilevel models predicting allostatic load over time are displayed in Table 3.5. Mean level of allostatic load was relatively high in the HRS sample, corresponding to slightly over four of the total ten biomarkers in a range of high clinical risk. The two samples showed disparate patterns of change over time, with average allostatic load scores increasing across the eight-year follow-up in HRS but showing no significant mean-level change over time in the ELSA sample. Considering the between-person effects of sense of purpose in life in the HRS, higher sense of purpose was associated with lower levels of physiological dysregulation across the study, 95% CI [-0.27, -0.17], but did not predict rate of change in allostatic load over time. The within-person effect of sense of purpose in the HRS model was not statistically significant, indicating that participants did not exhibit coupled patterns of change in allostatic load and sense of purpose relative to their typical levels across measurement occasions.

Table 3.5

Multilevel Model Results Predicting Longitudinal Change in Allostatic Load

	HRS	ELSA

Parameter	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
Intercept	4.087 (.036)	< .001	3.618 (.154)	< .001
Age	.039 (.002)	< .001	.016 (.010)	.087
Female	-.217 (.042)	< .001	.122 (.170)	.473
Race	.387 (.042)	< .001	--	
Education	-.075 (.008)	< .001	-.164 (.181)	.365
Depressive symptoms	.082 (.012)	< .001	.084 (.053)	.116
Sense of purpose	-.221 (.027)	< .001	-.153 (.096)	.111
Slope	.041 (.006)	< .001	-.028 (.022)	.201
Age	.000 (.000)	.898	-.002 (.001)	.220
Female	.008 (.007)	.230	-.015 (.021)	.478
Race	.003 (.010)	.762	--	
Education	-.001 (.001)	.508	.010 (.021)	.625
Depressive symptoms	-.005 (.002)	.013	.003 (.006)	.659
Sense of purpose	-.002 (.005)	.683	-.003 (.012)	.829
Within-person predictors				
Sense of purpose	.009 (.022)	.696	--	
Random coefficients				
Level-1 residual variance	.826 (.023)	< .001	.868 (.075)	< .001
Intercept residual variance	1.050 (.033)	< .001	1.150 (.127)	< .001
Slope residual variance	.002 (.001)	.013	.001 (.002)	.754

In ELSA, sense of purpose did not predict allostatic load in the fully adjusted model. However, throughout the model building process, sense of purpose in life was associated with lower level of allostatic load (intercept), though this effect was no longer statistically significant when number of depressive symptoms was included in the model, 95% CI [-0.34, 0.03]. An exploratory model excluding sense of purpose revealed that depressive symptomatology was significantly associated with allostatic load, suggesting that the sense of purpose and depressive symptoms variables in ELSA were accounting for much of the same variability in allostatic load. Results of the partially adjusted model accounting for sense of purpose, age, sex, and educational attainment are displayed in Appendix A, along with the exploratory model excluding sense of purpose. Other covariates also failed to predict allostatic load in the fully adjusted ELSA model.

Sensitivity Analyses

Additional models were run excluding the anthropometric markers grip strength and peak expiratory flow from allostatic load computations. Results of these models are presented in Table 3.6. Overall, the pattern of results remained similar to those reported above, with the exception of the slope effects. The slope in the previous HRS model suggested an overall pattern of increasing allostatic load across time, but in this model using only blood-based biomarkers, the slope was no longer statistically significant. Likewise, the previous ELSA model showing no mean-level change over time was contrasted with the current model indicating slight annual declines in allostatic load scores computed from blood markers. Taken together, these findings suggest a pattern of increasing risk profiles with time on anthropometric markers, but more variability in overall long-term changes on blood markers of cardiovascular, immune, and metabolic function. Considering the effects of purpose, sense of purpose remained associated with lower levels of this alternative allostatic load index in the HRS, though this effect was somewhat diminished relative to the main analyses. In ELSA, the majority of covariates, including sense of purpose in life, did not predict allostatic load.

Table 3.6

Multilevel Model Results Predicting Allostatic Load Scores Computed with Blood-Based Biomarkers

	HRS		ELSA	
Parameter	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
Intercept	3.180 (.032)	< .001	3.180 (.147)	< .001
Age	.006 (.002)	.006	.003 (.009)	.728
Female	-.220 (.039)	< .001	.176 (.167)	.293
Race	.312 (.056)	< .001	--	
Education	-.057 (.007)	< .001	-.188 (.180)	.297
Depressive symptoms	.056 (.011)	< .001	.073 (.053)	.166
Sense of purpose	-.130 (.025)	< .001	-.142 (.092)	.122
Slope	-.002 (.006)	.714	-.053 (.021)	.014
Age	-.001 (.000)	.036	-.003 (.001)	.033
Female	.011 (.006)	.080	-.012 (.021)	.556
Race	.005 (.009)	.581	--	
Education	-.001 (.002)	.285	.008 (.021)	.697
Depressive symptoms	-.003 (.002)	.081	.002 (.006)	.761
Sense of purpose	.000 (.004)	.970	-.002 (.011)	.855
Within-person predictors				
Sense of purpose	.029 (.020)	.148	--	

Random coefficients				
Level-1 residual variance	.726 (.020)	< .001	.775 (.067)	< .001
Intercept residual variance	.873 (.026)	< .001	1.085 (.155)	< .001
Slope residual variance	.001 (.001)	.071	.001 (.002)	.466

Discussion

Using data from two nationally representative longitudinal studies of aging, the present study examined the relationship between sense of purpose in life and three components of longitudinal allostatic load trajectories: (a) between-person differences in level of allostatic load (intercepts); (b) between-person differences in trajectories of allostatic change (slopes); and (c) occasion-specific intraindividual associations between time-varying sense of purpose and allostatic load after accounting for individual linear trajectories (coupled within-person effects). For between-person intercept effects (a), the present work found that middle-aged and older adults higher in sense of purpose scored lower on levels of allostatic burden across the follow-up period. In the HRS sample, this association held after adjusting for sociodemographic predictors and depressive symptoms. In ELSA, similar magnitude associations were observed with sense of purpose and lower level of allostatic load. However, this did not reach the threshold for statistical significance when depressive symptoms were accounted for, suggesting that much of this effect could be explained by shared associations between sense of purpose and depressive symptomatology. Sense of purpose in life was not related to between-person differences in slopes (b) or with coupled within-person effects (c).

These findings build upon previous work demonstrating between-person associations between sense of purpose and allostatic load (Zilioli et al., 2015). The research by Zilioli and colleagues suggested an inverse relationship between sense of purpose in life and allostatic load measured at a single ten-year follow-up, aligning with the present findings showing more purposeful individuals to have consistently lower allostatic burden over repeated biomarker assessments. Sense of purpose demonstrated small correlations with many of the individual biological indicators, replicating previous investigations in other samples. For instance, previous work has found adults higher in sense of purpose to have higher levels of the protective high-density lipoprotein cholesterol (Ryff et al., 2004) and lower C reactive protein (Friedman & Ryff, 2012), two findings which were replicated in the HRS cohort. The strongest correlations in the HRS were observed with anthropometric markers, which were further underscored by sensitivity analyses showing diminished effect of sense of purpose on allostatic load scores computed without peak expiratory flow and grip strength. These results highlight some potential mechanistic pathways linking sense of purpose with allostatic load and physical health more broadly.

Sense of purpose appeared most strongly associated with peak expiratory flow and grip strength, two functional biomarkers greatly influenced by physical activity (Dodds et al., 2013; O’Donovan & Hamer, 2018). Sense of purpose has been linked to greater engagement across numerous indicators of physical activity (Hooker & Masters, 2016; E. S. Kim et al., 2020; Z. Zhang & Chen, 2021). As well, sense of purpose is associated with reduced conflict-related neural activity during health decision-making involving physical activity and tempting alternatives (Kang et al., 2019). Given this link between higher sense of purpose and an active lifestyle, associations between sense of purpose and indicators of biological functioning could represent downstream benefits driven by increased engagement in active pursuits. On the other hand, the association between sense of purpose and allostatic load computed solely from blood-derived markers remained significant in HRS, pointing to the potential for multiple pathways connecting sense of purpose with better physiological regulation. Indeed, while depressive symptoms appeared to mediate associations between sense of purpose and allostatic load in ELSA, inclusion of this variable in HRS led to only a slight reduction in purpose-allostatic intercept associations. This finding points to a possible partial mediation through depressive symptomatology, with other factors unaccounted for in the model likely also influencing the relationship between sense of purpose and allostatic load. A likely mediating factor is regulation of stress processes, with past research demonstrating efficient reversal of sympathetic nervous system responses and faster recovery following a stressor exposure in participants high in sense of purpose (Fogelman & Canli, 2015; Ishida & Okada, 2006). A buffering effect of sense of purpose in life on chronic activation of the stress response would likely minimize over-activation of the hypothalamic-pituitary-adrenal axis and interconnected systems impacted by allostatic load (Juster et al., 2010).

More broadly, the present results underscore the need for additional research to examine the timing and magnitude of associations between sense of purpose and longitudinal health trajectories across the lifespan. While a considerable body of evidence from survival modeling points to sense of purpose predicting reduced risk for a host of chronic health conditions and changes in functional markers (E. S. Kim, Sun, Park, & Peterson, 2013; E. S. Kim et al., 2017), there is a paucity of studies evaluating the within- and between-person dynamics of sense of purpose and continuous markers of health across time. The present findings lend support to sense of purpose promoting preserved differentiation in allostatic load, with middle and older adults higher in sense of purpose showing reduced allostatic burden but no differences in changes in allostatic trajectory. Further, there is also the possibility that allostatic load scores computed as a sum of biomarkers in high-risk ranges may be less sensitive to longitudinal changes in underlying health, and sense of purpose may be more attune to change in levels of individual biomarkers over time. Recent research in the HRS sample observed coupled within-person associations of sense of purpose with cognition, wherein participants scored higher of tests of mental status and word recall on occasions when their reported sense of purpose was higher than what was typical for them across the study (Lewis & Hill, 2021). Establishing associations between interindividual changes in sense of purpose and concurrent changes in markers biological health would further reinforce the utility of purpose-targeting interventions to promote healthy aging. Sense of purpose in life has been shown to be modifiable through brief interventions (Friedman et al., 2017)

Limitations and Future Directions

Despite the uses of population-weighting techniques, the selectivity of respondents in the ELSA sample represents a primary limitation of this study. Response to the measure of sense of purpose, and therefore inclusion in the present sample, was based on completion of an optional self-completed supplement to the main ELSA data collection at only one time point. Thus, while the ELSA sample was selected for its representativeness of the English adult population, this sub-sample may be more heavily impacted by selection biases. Self-completed responses to this survey may have skewed more heavily towards participants with better health and well-being, as these individuals may be more inclined to respond to the optional mail-in survey about well-being and beliefs (Sutton & Edlund, 2019). Some evidence for this potential selection bias comes from ELSA participants in the present sample showing mean-level declines in blood-based biomarkers over time, despite the typical increasing pattern of these markers in older adulthood (Jenkins et al., 2022). Thus, some caution is warranted in interpreting the present ELSA results outside the context of this more selective subgroup. Inclusion of the sense of purpose in life measure in the main battery of ELSA assessments across multiple occasions would greatly strengthen the impact of purpose-related research in this sample.

The present study was also limited in availability of several contextual factors surrounding high biological risk profiles, such as participant awareness of risk or pursuit of medical advice. For instance, use of preventative healthcare screenings, medication use, and adherence to physician-recommended lifestyle changes in those at increased health risk, could account for differences in trajectories of allostatic load. That is, an increase of biomarkers into a clinical risk range may prompt changes in health habits, thereby muting potential within-person coupled associations with sense of purpose at subsequent assessments. Given the large four-year interval period between biomarker assessments in both samples, unobserved lifestyle changes could modify potential associations of sense of purpose with allostatic change. With sense of purpose predicting greater treatment adherence and preventative healthcare use (E. S. Kim et al., 2014; Musich et al., 2018), future investigations could utilize such contextual factors to further clarify longitudinal dynamics of sense of purpose and allostatic load. Beyond this, accounting for use of medications such as antihypertensive treatments could further improve estimates of long-term change in allostatic burden.

Conclusion

Though further research is warranted to elaborate on potential mechanisms, the present investigation supports sense of purpose predicting preserved differentiation of allostatic regulation, with more purposeful individuals demonstrating consistently lower allostatic load over time.

Chapter 4 – Project 3

Daily Ratings of Sense of Purpose in Life and Cognitive Performance in Older Adults: An Ecological Momentary Assessment Design

Abstract

Sense of purpose has been consistently linked with markers of health and positive development across the lifespan including higher educational attainment, better cognitive performance, and reduced risk for cognitive impairment. However, little is known about the mechanisms linking purpose in life with health and behaviours over the short-term. This research investigated daily dynamics among sense of purpose, cognition, and physical activity to clarify the mechanisms linking purposefulness with better cognitive health outcomes and to inform potential behavioural interventions using an ecological momentary assessment design. Multilevel models were used to test within- and between-person associations between end of day sense of purpose ratings and daily performance on five indices of cognitive functioning within a two-week period. Results showed no associations between daily ratings of purposefulness and cognitive performance at the within- and between-person level. There are some indications that the measurement of sense of purpose in daily assessments may be capturing a different construct relative to more extensive validated measures. Future research using intensive measurement design data is needed to clarify the multilevel factor structure and reliability of measures of sense of purpose across short timespans.

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*My contributions as primary author represent study conceptualization, design, data analysis, and manuscript preparation. Coauthors were included based on mutual contributions to data collection, as well as cleaning and compiling data for analyses.

Introduction

Past theoretical work has defined purpose in life as a central, self-organizing life aim serving as an overarching framework towards which individuals direct their everyday behaviour and goals. (McKnight & Kashdan, 2009). This definition implies that having a sense of purpose in life helps to drive individuals towards behaviours congruent with long-term goals—the advancement of one's career, supporting health and personal relationships, or other components central to one's purpose (Hill et al., 2010; Lewis, 2020). Indeed, sense of purpose has consistently been linked with markers of health and positive development across the lifespan including reduced risk of delinquency among youth, higher educational attainment, better cognitive performance, and reduced risk for cognitive impairment (Hill, Edmonds, et al., 2016; Hill & Weston, 2019; Lewis et al., 2017). However, most of the research in this area has relied on cross-sectional data or focused on between-person differences in effects of sense of purpose over widely spaced assessments spanning years. Consequently, very little is known about the mechanisms linking purpose in life with health and behaviours over the short-term.

Recent technological advances may help facilitate the use of minimally invasive ecological momentary assessment designs (EMA; also known as intensive measurement or daily diary studies, e.g., Shiffman et al., 2008) to study these dynamics in more natural settings. Such designs provide valuable insight into shorter-term variation in constructs found to be relatively stable in widely spaced longitudinal designs. For instance, recent EMA of cognitive functioning has found considerable fluctuation in cognitive capacity within and across days, which may be impacted by situational, emotional and other contextual factors in a given moment (Schmitter-Edgecombe et al., 2020). Moreover, recent EMA research suggests that around half of the variability in sense of purpose in life occurs within persons and within days (Hill et al., 2021;

Pfund et al., 2021), highlighting the need for understanding factors that contribute and correlate with these fluctuations. Project 3 intends to build upon this past research using EMA to examine within-person dynamics of sense of purpose, cognitive performance, and physical activity across a two-week period. The first aim is to test associations between daily ratings of sense of purpose and performance on five cognitive tests of memory, processing speed, and executive functioning. A better understanding of relationships between sense of purpose, and cognition over the short-term would further clarify the mechanisms linking purposefulness with better cognitive health outcomes and could inform behavioural interventions aimed at supporting sense of purpose.

Methods

Participants and Procedures

This project used data from the Daily Affect, Stress, and Health (DASH) survey, an EMA design study of 65 community-dwelling older adults from the greater Victoria area. Over a period of two weeks, DASH participants completed ambulatory measures of cognitive functioning, health, and well-being four times per day and wore wrist-based bio-monitors to passively record physical activity, heart rate, and sleep. Participants were recruited in 2019 via posters placed in public areas, senior and community centres, the University of Victoria Institute on Aging and Lifelong Health newsletter and through circulation of an online flyer with leaders of local clubs and community organisations. The poster and flyer provided basic information about the requirements and aims of the study and invited interested individuals to contact the iLifespan lab via phone call or email. Interested older adults were contacted and administered a telephone screening assessment to assess eligibility prior to enrollment. Participants were invited to participate in the study if they were aged 65 to 75, were fluent in English, had access to Wi-Fi, did not have severe or uncorrected vision or hearing problems, and had no cognitive or neurological impairment that could impact assessment.

Eligible participants completed an in-lab visit where they were given instructions on use of the mobile phone and Fitbit devices used in the study and were instructed on procedures for completing the mobile assessments over the two-week study period. Participants completed a detailed initial survey assessing demographic information, health, and well-being. Participants were provided a $25 honorarium at the end of the intake session and as well as an instructional guide for the study devices to take home with them, which included descriptions and pictures outlining proper measurement procedures. Over the next 14 days, participants used the mobile devices to complete brief five-minute surveys twice throughout the day, and longer surveys of about 15 minutes in the morning and evenings. The five-minute EMA surveys consisted of brief cognitive tasks, as well as questions about psychological and environmental factors such as current mood, location, and stress. Study participants were instructed to complete the first brief EMA survey within 30-minutes of waking. For the remaining two brief surveys (the “Beeped” surveys), a notification and alarm would sound on the mobile devices at two random points in the day, instructing participants to complete the survey within the next 30-minutes.

The end of day survey was completed every evening within one hour of going to bed, and involved the same tests of cognitive functioning, stress, and other contexts, as well as more detailed reflections on their experiences of the day. Participants completed a mobile survey of their health, well-being, and mood over the course of the day and reported any alcohol or drugs they had used during this time. Reminder notifications to complete the end of day survey were sent to the mobile devices every evening at 7:00pm.

This measurement procedure was followed for a total of 14 days, excluding the initial day on which they completed the intake assessment. Shortly after this 14-day period, an in-lab debrief session was completed where participants returned the devices, were granted a $50 honorarium, and completed a final brief survey. Participants were not required to complete assessments beyond the two-week period, though some chose to do so (n = 5) and these additional responses were included in analyses. Recruitment for this study was terminated in the spring of 2020 in response to the COVID-19 global pandemic. The project was approved by the University of Victoria Human Research Ethics Board in the spring of 2019 under ethics protocol number 18-1069.

Measures

Sense of Purpose in Life

At study intake, participants completed a computer-based survey including the three-item purpose in life measure from the Ryff Psychological Wellbeing Scale (Ryff & Keyes, 1995). Scores on this three-item Ryff scale demonstrated very poor internal consistency, Cronbach's α = .42. In addition, at the end of each day, participants reported via their mobile devices how much they felt that they had purpose that day on a scale from 0 to 100. These daily sense of purpose ratings were used for the main analytic models.

Cognitive Functioning

Cognitive functioning was assessed using five ambulatory cognitive tasks administered using smartphones: dot memory, symbol search, colour dot, colour shape, and Stroop tasks. Visual examples of each of the five cognitive tasks are provided in Appendix A. These tasks have been developed specifically for mobile devices and have been found to be reliable measures of cognitive performance for use in EMA designs (Sliwinski et al., 2018). Participants were given verbal and written instructions for each of the cognitive tasks during the in-lab intake session and completed practice trials to ensure that they understood the requirements of each task. Responses were excluded on all occasions in which there were incomplete trials, indicating the participant did not complete the task, as well as on occasions where surveys were force closed or had timed out. Based on these criteria, eight out of 42391 trials were excluded for symbol search, 93 out of 7077 trials for colour dot, 94 out of 7098 trials for dot memory, 124 out of 11194 trials for colour shape, and 246 out of 7098 trials for the Stroop task. Trial exclusions increase linearly as the cognitive tasks were consistently presented in this order. We also visually examined the distribution of reaction time for each cognitive variable, and made decisions as a lab regarding exclusion of trials that were not completed within an appropriate amount of time. Eligibility times, in seconds, and resulting excluded trials are reported in each of the following subsections that detail each cognitive task.

Dot Memory. The dot memory task of working memory assessed the ability of participants to recall the placement of three dots after completing a distractor task. Participants were presented with three red dots placed within a 5×5 grid and asked to remember the dot locations. After a three-second period, the grid was removed and replaced with a distractor task in which participants were required to tap several letter Fs placed among a series of Es. After eight seconds of the distractor task, an empty 5×5 grid would appear on the screen and participants were prompted to indicate the original location of the three dots. Scores on the dot memory task were computed as the sum of the Euclidean distance of each true dot location from the nearest respondent dot position. Thus, scores indicate distance from the correct locations in grid units, with zero representing correct placement of all three dots and higher values indicating a greater discrepancy between participant recall and correct dot locations. Responses ranging from 0.5 to 25 seconds were included, which resulted in exclusion of 148 trials (2.11% of the dot memory trials). Two dot memory trials were completed at each of the cognitive assessments four times per day, with scores computed as the mean across all trials in the day. Scores on this ambulatory measure have been found to correlate highly with laboratory measures of working memory (Sliwinski et al., 2018).

Symbol Search. Participants were presented with a row of three cards at the top of the screen containing a pair of symbols, along with two card options at the bottom of the screen. Participants were instructed to decide as quickly as possible which symbol pair cards at the bottom of the screen matched one of the cards at the top of the screen. Participants completed 12 symbol search trials at each of the four sessions per day, with score compute as the daily mean across trials. At each session, between 25% and 50% of trials involved more challenging "lure" trials in which one symbol on the incorrect response card matched a symbol on one of the symbol pairs at the top of the screen. Some sessions were excluded based on reaction time (inclusion eligibility= 0.5-5.5 seconds), which resulted in excluding 1286 trials (3% of the symbol search trials). Scores on this task were computed as mean response time in milliseconds for correct trials. This task requires speeded comparisons similar to standard laboratory tests and has been found to be comparable to common measures of perceptual speed (Sliwinski et al., 2018).

Colour Dot. At the start of the colour dot task, participants were presented with three differently coloured dots and asked to remember their colours and placement. After a brief encoding period, the dots disappear and are replaced by an empty square. After a delay, participants are presented with a blank dot and asked to recall the colour of the dot corresponding to that location. Following this, participants are then asked to indicate the location of a specific-coloured dot within the geographical space. Scores were computed as the Euclidean distance of the dot placement from the correct location within a 450×450 grid, with lower values indicating placement closer to the correct location. Based on reaction time eligibility (0.5-7.5 seconds), 246 trials were excluded (3.6% of the colour dot trials).

Colour Shape. Participants are presented with three differently coloured irregular shapes and asked to remember their shape and colour. After a brief encoding period, the shapes disappear. The same shapes then return to the screen in different locations and may differ in orientation and colour. Participants are asked to indicate whether the shapes are coloured the same or differently from their initial presentation. The colour shape task was administered in only the morning and evening surveys, with six colour shape trials completed per session. A total of 286 trials (3.5% of colour shape trials) were excluded based on reaction time falling outside of 0.5 to 6.0 second thresholds.

Stroop Task. The Stroop task (Stroop, 1935), a well-established measure of processing speed and response inhibition, was administered to participants twice per day as part of the morning and evening surveys. Participants were presented with coloured words and asked to report the colour of the font as quickly as possible by selecting one of the two colour response options. Each session consisted of 12 trials, with between five and seven being incongruent trials wherein the font colour was different from the word (e.g., the word "orange" written in yellow font). Scores on this task were computed as the summed reaction time across congruent and incongruent trials in milliseconds, with lower values indicating faster processing speed. Some trials were excluded based on reaction time (eligibility = 0.5-3.5 seconds), which resulted in excluding 536 trials (2.4% of the Stroop task trials). A similar ambulatory Stroop measure has been previously found to be reliable in the mobile assessment of perceptual speed and attentional biases (Waters & Li, 2008).

Covariates

Models also adjusted for age, sex, education, perceived daily stress, and daily average effort ratings. Age was assessed in years and centered on the sample mean. Sex was assessed by a categorical item with the following response options: female, male, intersex, and other. All participants chose male or female options and responses were dichotomized with females as the reference category. Participants were also asked to indicate their highest level of education obtained from the following categorical response options in which higher values indicate more education: 1=did not complete high school; 2=high school; 3=trade school; 4=some university/college; 5=undergraduate degree; 6=graduate, law or medical school. Responses were dichotomized such that a value of 1 indicated completion of a university or college degree or higher. Perceived stress was assessed at the daily level using a modified five-item version of the Perceived Stress Scale (S. Cohen et al., 1994). Participants rated the amount of effort they put into the cognitive tasks at the end of each session on a 0 to 100 scale, and these values were averaged at the daily level for the present analyses.

Statistical Analyses

Addressing the first aim of this project, a series of multilevel models tested associations between daily ratings of sense of purpose in life with performance on each of the cognitive tasks. Daily cognitive functioning on each task were predicted by within- and between-person sense of purpose and the covariates age, sex, education, and stressors. At the daily level (Level 1), predictors included daily ratings of sense of purpose, presence of reported stressors that day, self-reported effort, and day in study (centered on the first study day) to account for potential learning effects. Person-mean values across the two-weeks were included at the between-person level (Level 2) to examine effects of trait levels of sense of purpose (PurposeBP) and stressors (StressBP). All covariates at the between-person level were grand-mean centered. A summary of the multilevel models for aim one is provided below.

Level 1:

$$Cognition_{ti} = \beta_{0i} + \beta_{1i}(Day) + \beta_{2i}(DailyPurpose) + \beta_{3i}(DailyStress) + \beta_{4i}(Effort) + e_{ti}$$

Level 2:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(Age) + \gamma_{02}(Sex) + \gamma_{03}(Education) + \gamma_{04}(PurposeBP) + \gamma_{05}(StressBP) + \mu_{0i}$$

$$\beta_{1i} = \gamma_{10} + \mu_{1i}$$

$$\beta_{2i} = \gamma_{20} + \mu_{2i}$$

$$\beta_{3i} = \gamma_{30} + \mu_{3i}$$

Where $Cognition_{ti}$ represents the score for each of the five ambulatory cognitive assessments for individual *i* on day *t*, expressed as a function of a person-specific random intercept (β_{0i}) and linear change across the study period (β_{1i}). Predicted cognitive score is based on within-person fluctuation in daily ratings of sense of purpose in life relative to that individual's typical levels (β_{2i}), as well as person-mean centered daily ratings of stress (β_{3i}) and effort (β_{4i}). At level 2, covariates were included on the intercept effect to account for potential between-person differences in cognition based on age, sex, education, sense of purpose, and stress (γ_{01} to γ_{05}).

Results

Table 4.1 presents descriptive statistics and demographic information for the present sample. Overall response rate in the sample was high. Participants completed 3321 of a possible 3640 ambulatory assessments (91.24%) across the two-week period, corresponding to an average of 50.31 of a total 56 ambulatory assessments per participant. An intercept-only multilevel model for daily ratings of sense of purpose was fit to compute intraclass correlation. Based on this model, roughly 28% of the variability in daily purpose ratings represented within-person differences in ratings across days, while 72% represented between-person variation. Individual trajectories of daily purpose across the 14-day period are depicted in Figure 4.1. Intercorrelations between daily ratings of purposefulness, baseline sense of purpose in life scores from the Ryff measure, and scores on the five cognitive tasks are presented in Table 4.2. Mean daily sense of purpose ratings were moderately correlated with the baseline four-item Ryff purpose measure but were not associated with cognitive scores.

Table 4.1

Descriptive Statistics for the DASH Sample

Variable	*M* (*SD*)/%	Range
N	65	
Age, years	70.76 (3.48)	64-78
Sex, female	46 (70.77%)	
Education		
High School/some post-secondary	27.42%	
Post-secondary degree	32.26%	
Graduate, Law, Medical Degree	40.32%	

Ethnicity, Caucasian	55 (84.62%)	
Daily purpose	75.77 (15.89)	32.38-100
Physical activity, minutes	53.84 (51.75)	0-204
Perceived stress	19.22 (13.32)	1.54-53.85
Baseline purpose (Ryff measure)	5.46 (0.81)	4.00-7.00

Figure 4.1

Individual Trajectories in Sense of Purpose across the Follow-up Period

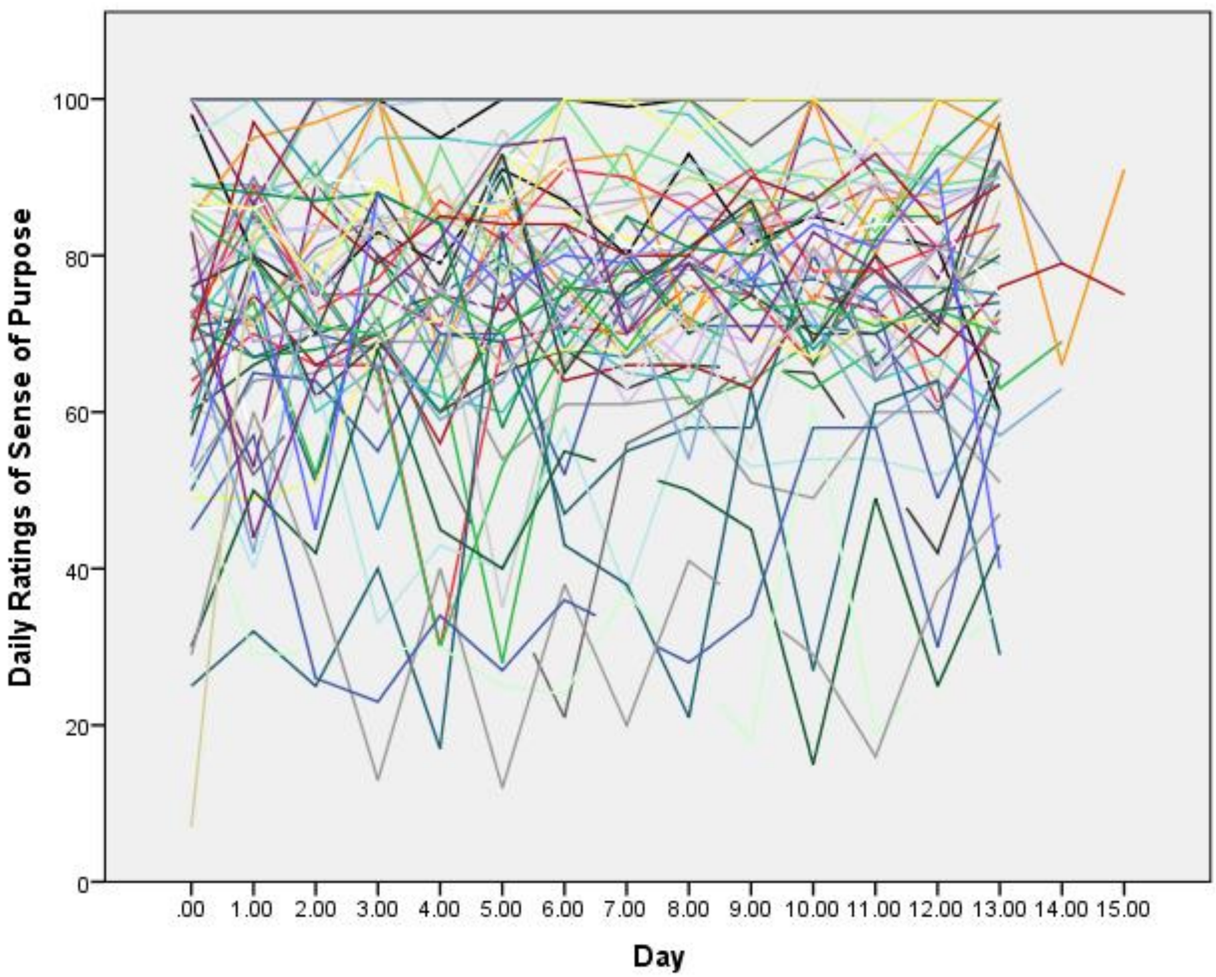


Table 4.2

Zero-Order Correlations among Daily and Baseline Sense of Purpose and Cognitive Tasks

Variable	1.	2.	3.	4.	5.	6.	7.
1. Daily purpose	1	.36**	.06	.07	.08	-.11	.10
2. Baseline purpose (Ryff)		1	-.15	-.10	-.14	-.07	.05
3. Dot memory			1	.35**	.54**	-.42**	.15
4. Symbol search				1	.52**	-.35**	.43**
5. Colour dot					1	-.35**	.06
6. Colour shape						1	.02
7. Stroop							1

Note. **p* < .05. ***p* < .01.

Results from the multilevel models predicting daily cognitive functioning are presented in five main parts, corresponding to the five cognitive tasks serving as the outcome variable in each of the models. Figures representing individual trajectories for day means in each of the five cognitive tasks across the 14-day period are presented in Appendix C. Learning effects were observed for each cognitive task, with participants improving on each outcome across the study period. For each cognitive outcome, intraclass correlation coefficients (ICC) were first computed from intercept-only models, followed by sequential model building. Beginning with a simple model including within- and between-person sense of purpose in life (Model 1), covariates were added to the models in steps, including the demographic variables age, sex, and education (Model 2), and time-varying predictors of daily stress and self-reported effort (Model 3). Akaike Information Criteria (AIC) values are reported for each model to aid in evaluation of fit to the data and comparisons between related models.

Dot Memory

According to the intercept-only model, 61% of the variability in dot memory accuracy was between-persons, with the remaining 39% indicating within-participant variability across measurement occasions. Results from models predicting dot memory accuracy are presented in Table 4.3. At the within-person level, sense of purpose had very small positive associations with accuracy distance, suggesting slightly worse recall of dot placement on days when participants reported feeling more purposeful than what was typical for them. However, this effect was marginal and may reflect random variability in the data. Similarly, a small, marginal association was found where participants with higher average sense of purpose ratings across the study showed small increases in recall distance from correct dot placement. Older participants had slightly less accurate recall of dot locations on average.

Table 4.3

Fixed and Random Effects of Models Predicting Dot Memory Accuracy

	Model 1		Model 2		Model 3	
	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
Within-Person Predictors						
Purpose (WP)	0.02 (0.01)	.084	0.02 (0.01)	.156	0.02 (0.01)	.067
Stress (WP)					0.02 (.01)	.195
Effort					-0.02 (0.04)	.630
Intercept	10.30 (0.55)	<.001	12.78 (1.02)	<.001	12.37 (1.19)	<.001
Purpose (BP)	0.03 (0.04)	.341	0.04 (0.03)	.258	0.07 (0.04)	.064
Age			0.25 (0.13)	.054	0.25 (0.12)	.046
Sex			-2.17 (1.07)	.042	-2.06 (1.44)	.152

Education			-2.62 (1.20)	.028	-2.08 (1.53)	.175
Stress (BP)					0.06 (0.06)	.274
Slope	-0.29 (0.04)	<.001	-0.28 (0.04)	<.001	-0.28 (0.04)	<.001
Random coefficients						
Level-1 residual	8.50 (0.51)	<.001	8.43 (0.54)	<.001	8.38 (0.53)	<.001
Intercept residual	16.18 (3.16)	<.001	12.99 (2.46)	<.001	12.37 (1.19)	<.001
Slope residual	0.04 (0.01)	.002	0.04 (0.01)	.002	0.04 (0.01)	.003
AIC	4537.32		4308.69		4314.73	

Note. WP = Within-person centered variables. BP = Between-person centered variables. AIC = Akaike's Information Criterion.

Symbol Search

Reaction time on the symbol search task demonstrated the highest proportion of between-person variability of the five cognitive outcomes, with three quarters of variability occurring at the between-person level (ICC = .75). Sense of purpose was unrelated to symbol search reaction time at the within-person level (see Table 4.4). At the between-person level, more purposeful participants were found to have slightly slower initial reaction time (corresponding to less than 10 milliseconds), however, this was only observed when time-varying stress was included in the model. A model similar to Model 3 with stress excluded revealed a comparably smaller, non-significant association between sense of purpose and the reaction time intercept (b = 2.39, SE = 3.63, p =.510), suggesting that the effect reported in Model 3 may be an artifact of mutual associations between daily purpose and stress.

Table 4.4

Fixed and Random Effects of Models Predicting Symbol Search Reaction Time

	Model 1		Model 2		Model 3	
	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
WP Predictors						
Purpose (WP)	-0.30 (0.82)	.714	-0.55 (0.80)	.493	-0.72 (0.85)	.399
Stress (WP)					-0.52 (0.61)	.396
Effort					1.10 (1.52)	.469
Intercept	2569.94 (60.99)	<.001	2624.46 (125.12)	<.001	2578.14 (118.06)	<.001
Purpose (BP)	2.82 (3.94)	.475	2.56 (3.67)	.485	9.64 (4.22)	.022
Age			20.41 (17.75)	.250	23.58 (15.86)	.137
Sex			88.75 (164.17)	.589	78.58 (148.25)	.596
Education			-101.44 (144.99)	.484	-29.00 (149.83)	.847
Stress (BP)					13.57 (6.56)	.038
Slope	-32.79 (3.15)	<.001	-32.13 (3.19)	<.001	-32.25 (3.25)	<.001
Random coefficients						
Level-1 residual	35911 (2760.87)	<.001	36340 (2876.16)	<.001	36160 (2868.07)	<.001
Intercept residual	19894(41377)	<.001	187553(39349)	<.001	185607(40973)	<.001
Slope residual	424.95 (107.24)	<.001	416.69 (106.97)	<.001	403.19 (106.99)	<.001
AIC	11863.39		11309.15		11312.76	

Note. WP = Within-person centered variables. BP = Between-person centered variables. AIC = Akaike's Information Criterion.

Colour Dot

Accuracy on the colour dot task was highly variable within-persons, with 62% of the variability corresponding to fluctuations in participant scores across assessments (ICC = 0.38).

Sense of purpose in life, along with all other modeled covariates, did not predict colour dot accuracy scores (see Table 4.5).

Table 4.5

Fixed and Random Effects of Models Predicting Colour Dot Accuracy

	Model 1		Model 2		Model 3	
	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
WP Predictors						
Purpose (WP)	-0.07 (0.07)	.352	-0.06 (0.07)	.434	-0.04 (0.08)	.646
Stress (WP)					0.07 (0.07)	.273
Effort					-0.08 (0.15)	.589
Intercept	64.72 (3.13)	<.001	72.14 (4.52)	<.001	70.98 (4.34)	<.001
Purpose (BP)	0.15 (0.17)	.372	0.13 (0.15)	.386	0.33 (0.18)	.076
Age			0.50 (0.92)	.589	0.59 (0.97)	.543
Sex			-2.96 (4.82)	.540	-0.71 (4.76)	.881
Education			-8.48 (4.70)	.071	-7.08 (4.49)	.115
Stress (BP)					0.38 (0.21)	.072
Slope	-1.30 (0.26)	<.001	-1.34 (0.27)	<.001	-1.27 (0.29)	<.001
Random coefficients						
Level-1 residual	327.59(36.51)	<.001	341.86(39.17)	<.001	339.20(43.08)	<.001
Intercept residual	316.35(158.47)	.046	259.45(172.88)	.133	70.98 (4.33)	<.001
Slope residual	1.02 (1.23)	.404	0.86 (1.34)	.523	0.67 (1.40)	.632
AIC	7612.32		7270.82		7272.17	

Note. WP = Within-person centered variables. BP = Between-person centered variables. AIC = Akaike's Information Criterion.

Colour Shape

The basic model for colour shape accuracy indicated an ICC value of .41, suggesting 41% of variance in colour shape scores could be attributed to person-level clustering. Models predicting proportion of correct colour shape trials had convergence issues related to the small range of the dependent variable and were rescaled by multiplying scores by 100 (representing percentage correct colour dot trials). Results of these rescaled models are presented in Table 4.6. Similar to the symbol search results, between-person sense of purpose predicted slightly smaller percentage of correct trials, but this effect was only observed when stress was included in the model. This between-person effect of sense of purpose was considerably smaller in magnitude and not statistically significant when adjusting for all covariates excluding for stress (b = -0.10, SE = 0.11, p = .375).

Table 4.6

Fixed and Random Effects of Models Predicting Colour Shape Accuracy

	Model 1		Model 2		Model 3	
	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
WP Predictors						
Purpose (WP)	0.04 (0.05)	.350	0.03 (0.05)	.477	0.04 (0.06)	.534
Stress (WP)					0.02 (0.06)	.754
Effort					0.05 (0.20)	.801
Intercept	69.68 (1.55)	<.001	74.88 (27.09)	.006	67.89 (13.25)	<.001

Purpose (BP)	0.04 (0.05)	.350	-0.09 (0.10)	.372	-0.26 (0.12)	.032
Age			-0.13 (0.38)	.738	-0.12 (0.37)	.744
Sex			1.60 (3.25)	.622	1.56 (14.51)	.914
Education			3.74 (2.87)	.192	1.12 (22.10)	.960
Stress (BP)					-0.30 (0.16)	.056
Slope	0.81 (0.14)	<.001	0.83 (0.15)	<.001	0.81 (0.47)	.084
Random coefficients						
Level-1 residual	131.74 (7.41)	<.001	132.96 (7.45)	<.001	133.28 (11.55)	<.001
Intercept residual	98.20 (18.48)	<.001	92.56 (19.53)	<.001	67.89 (13.25)	<.001
Slope residual	0.44 (0.19)	.022	0.48 (0.21)	.019	0.48 (0.21)	.019
AIC	6818.11		6504.79		6509.64	

Note. WP = Within-person centered variables. BP = Between-person centered variables. AIC = Akaike's Information Criterion.

Stroop Task

Based on the intercept-only model, 69% of daily mean reaction time on the Stroop task differed between-persons. Sense of purpose did not predict overall level or coupled within-person changes in Stroop performance (see Table 4.7). Participants had slightly longer reaction time on Stroop tasks on days in which they reported placing more effort into cognitive assessments than what was typical for them.

Table 4.7

Fixed and Random Effects of Models Predicting Stroop Task Reaction Time

	Model 1		Model 2		Model 3	

	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*	Estimate (*SE*)	*p*
WP Predictors						
Purpose (WP)	0.77 (0.58)	.179	0.76 (0.60)	.203	0.57 (0.65)	.379
Stress (WP)					-0.11 (0.54)	.842
Effort					3.45 (1.68)	.040
Intercept	1627.36 (33.65)	<.001	1624.96 (57.49)	<.001	1612.86 (63.77)	<.001
Purpose (BP)	1.97 (1.86)	.291	2.08 (1.88)	.268	4.99 (2.61)	.056
Age			-8.01 (10.55)	.448	-5.00 (9.58)	.602
Sex			-52.33 (82.69)	.527	-82.78 (83.89)	.324
Education			31.56 (68.28)	.644	54.49 (78.99)	.490
Stress (BP)					6.76 (3.46)	.050
Slope	-17.98 (2.50)	<.001	-18.28 (2.62)	<.001	-18.87 (2.60)	<.001
Random coefficients						
Level-1 residual	16186 (1890)	<.001	16667 (1957)	<.001	16148 (1940)	<.001
Intercept residual	64250 (11864)	<.001	64099 (12003)	<.001	58523 (11366)	<.001
Slope residual	291.74 (92.12)	.002	308.09 (97.58)	.002	294.62 (102.72)	.004
AIC	11136.09		10633.90		10629.15	

Note. WP = Within-person centered variables. BP = Between-person centered variables. AIC = Akaike's Information Criterion.

Discussion

To date, very few studies have utilized intensive measurement designs to examine the role of sense of purpose in daily life. Within-person changes in sense of purpose across days has been linked with greater positive affect and less negative affect (Hill et al., 2021), and other work has found higher positive social interactions within a day to predict higher end of day ratings of purposefulness (Pfund et al., 2021). Beyond this work, very little is known about the dynamics of sense of purpose measured at the daily level and within-person changes in behaviour and functioning. The present investigation is the first to my knowledge to examine associations between purposefulness and cognitive functioning at the daily level. This research expands upon a multitude of previous studies linking sense of purpose with better cognitive outcomes across the span of adulthood. Sense of purpose is consistently associated with better middle-aged and older adult cognitive performance across multiple indicators of cognitive functioning in several independent longitudinal studies with diverse measurement procedures, samples, and languages (Sutin, Luchetti, Stephan, et al., 2022).

Despite the accruing evidence suggesting that having a sense of purpose supports better cognitive aging, daily purpose in the present study did not show within-person or between-person associations with performance on five tests of cognitive functioning. Though these findings appear to contradict the prevailing body of research, such differences could be attributable to differing impacts of sense of purpose over short vs. long-term longitudinal examinations. As noted in the introductory chapter, sense of purpose may promote better cognitive outcomes through accumulation of benefits from lifestyle factors such as higher physical activity (Hooker & Masters, 2016) and increased engagement in mentally-stimulating pursuits (Lewis & Hill, 2020). These lifestyle correlates of sense of purpose would likely confer downstream protective effects on cognition, leading to differentiation of cognitive scores over time between individuals high and low in sense of purpose. However, associations between sense of purpose and these mediating pathways to cognition at the daily level may not be present, or could be insufficient to demonstrate associations over such a short timescale.

Another consideration is the distinction between trait and state level predictors of functioning. Sense of purpose is viewed as a relatively stable trait in middle and early older adulthood, akin to dispositional characteristics such as personality (Hill et al., 2015; Ko et al., 2016). Research on trait characteristics like the Big 5, have found traits to be robust predictors of general tendencies, but are notoriously poor predictors of behaviour at the situation level (Fleeson, 2004). For example, while an individual higher in trait sense of purpose may be viewed as being more goal-directed over the long-term, that individual's behaviour across situations is likely to be more variable, and other social, cognitive, or contextual factors may better explain how goal-directed they are in a given moment. Although asked at the daily level, the single item question assessing how purposeful participants felt that day may still pick up on trait-level characteristics of how purpose participants feel in general. Daily sense of purpose did fluctuate somewhat within participants across days, but these ratings were relatively stable when considering that 72% of the variability in sense of purpose occurred between-persons. This is relatively high compared to other EMA investigations (e.g., Pfund et al., 2021) showing a more even split for within- and between-person variability. Moving forward, an important direction for EMA designs will be to carefully consider phrasing of items to distinguish trait vs. state characteristics.

One additional possibility is that examining mean-level changes in cognitive performance could lack the sensitivity to detect subtle cognitive variations across days. Though there were within-person fluctuations around individual linear trajectories in cognition (see Appendix C), these may not have been of sufficient magnitude to observe potential influences of sense of purpose or other predictors at the within-person level. Underscoring this point, the covariates age, sex, education, and daily ratings of stress and effort did not consistently predict cognitive functioning on any of the five tasks. An alternative approach would be to examine fluctuations in sense of purpose as a predictor of within-person cognitive variability. Intraindividual variability may be a more sensitive indicator of underlying neurological dysfunction or temporal fluctuations in cognitive resources (Hultsch et al., 2007; MacDonald et al., 2009). Past research has found cognitive variability to be an indicator of brain health, with higher variability predicting dementia risk even after adjusting for level of cognitive functioning (Burton et al., 2006; Vaughan et al., 2013). At the daily level, higher intraindividual variability in cognitive scores across multiple trials may reflect a heightened susceptibility to fluctuations in attentional and cognitive resources throughout the day.

Limitations and Future Directions

The current project is limited in several ways which should inform future investigations in this area. To start, the current sample was highly educated and less ethnically diverse compared to the general older adult population. Further, the use of a single-item daily purpose measure may not fully capture aspects of sense of purpose in life relative to more extensive validated measures. Indeed, mean daily ratings of purposefulness were only moderately correlated with baseline scores on the three-item Ryff measure (Ryff & Keyes, 1995). Administration of longer validated measures of sense of purpose in intensive measurement designs, though more time consuming, would facilitate more detailed evaluation of correlates of daily and within-day purpose. Moreover, there is also uncertainty regarding the multilevel factor structure of measures of sense of purpose. Given the previously mentioned lack of microlongitudinal research on sense of purpose, little is known about whether conventional measures of purposefulness are valid across shorter-term timescales. Future research using multilevel confirmatory factor analysis techniques (Geldhof et al., 2014; Rush & Hofer, 2014) on intensive measurement design data is needed to clarify the multilevel factor structure and reliability of measures of sense of purpose across short timespans.

In sum, the present project examined daily dynamics of sense of purpose in life and performance on five cognitive tasks over a two-week period, finding little evidence for within-day associations between sense of purpose and cognition. There are some indications that the measurement of sense of purpose in daily assessments may be capturing a different construct relative to more extensive validated measures. Future research using intensive measurement design data is needed to clarify the multilevel factor structure and reliability of measures of sense of purpose across short timespans.

Chapter 5 – General Discussion

Through a series of three independent longitudinal investigations, the current dissertation examined associations between sense of purpose in life and indicators of cognition and functioning across multiple biological systems. In Project 1, more purposeful older adults were found to have lower prospective risk of developing mild cognitive impairment (and equivalent classification in HRS), later onset of impairment, and increased likelihood of improvement in cognitive functioning following MCI classification. These results were replicated across two independent longitudinal studies with disparate samples and measurement procedures. In Project 2, sense of purpose in life was associated with lower overall level of allostatic load across measurement occasions in two national longitudinal samples but did not predict rate of change or within-person fluctuations in allostatic burden across time. Finally, Project 3 examined daily dynamics of sense of purpose and cognitive functioning using intensive measurement design, finding no evidence for associations between daily ratings of purposefulness and performance on five cognitive tasks across a two-week period. These findings advance existing theory and highlight important directions for the field moving forward.

Sense of Purpose as a Resource for Healthy Cognitive Aging

Current treatments for Alzheimer’s disease and related dementias focus on reducing disruptive symptoms, but have shown little success in slowing or reversing progression of these diseases (Alzheimer’s Association, 2022). Given the limitations of available treatments, and the recognition that dementia is a multifaceted disease, there have been increased calls for evaluating the potential utility of non-pharmacological alternatives for mitigating dementia; including lifestyle risk factors, management of vascular and metabolic conditions, and psychosocial factors (Dominguez et al., 2021; Qiu et al., 2009). Sense of purpose in life has emerged as a potential therapeutic avenue given its association with better cognitive functioning and reduced dementia risk (Sutin, Luchetti, et al., 2021). In understanding how sense of purpose may support cognition in middle and older adulthood, it is important to distinguish normative cognitive functioning from non-normative declines attributable to cognitive impairment and dementia.

Considering normative cognitive functioning, sense of purpose is associated with several lifestyle factors known to support cognitive functions. For instance, sense of purpose is positively correlated with educational attainment and markers of socioeconomic standing (Hill, Turiano, et al., 2016), factors shown to predict better cognitive functioning later in life (van Hooren et al., 2007; M. Zhang et al., 2015). Furthermore, purposeful individuals tend to participate more frequently in leisure activities involving intellectual and social engagement (Lewis & Hill, 2020), have larger social networks (Scheier et al., 2006), and less loneliness (Kang et al., 2021; Sutin, Luchetti, Aschwanden, Lee, et al., 2022). The combination of these lifestyle pursuits may confer benefits for cognition across middle and older adulthood, allowing these individuals to attain and maintain higher levels of cognitive performance with advancing age.

In the context of non-normative cognitive change, Project 1 helps to advance the understanding of the role of sense of purpose in the timing of progression through states of cognitive impairment and dementia. Project 1 replicated previous work in the MAP sample in showing an association between sense of purpose and reduced risk of incident MCI (Boyle, Buchman, Barnes, et al., 2010), and also extended these findings in showing that this effect persisted after controlling for competing risk of death. Results from Project 1 and recent meta-analytical work point to sense of purpose being a robust predictor of lower cognitive impairment risk across a multitude of longitudinal samples with differing demographic characteristics, languages, and measurement procedures (Sutin, Aschwanden, et al., 2021). One mechanism through which sense of purpose may influence risk for non-normative cognitive change is through supporting cognitive reserve capacity of middle and older adults.

The theory of cognitive reserve suggests that some individuals are more resilient to neuropathology and are able to tolerate considerable neural insults before clinical symptoms emerge (Stern, 2002; Stern et al., 2019). Sense of purpose in life has been found to predict cognitive resilience in the MAP sample, with more purposeful older adults able to maintain better cognitive performance in spite of accumulating neuropathology (Boyle et al., 2012). In Project 1, participants higher in sense of purpose from the MAP and HRS samples demonstrated patterns of cognitive change consistent with cognitive reserve. That is, increased resilience to neuropathology in those high in reserve is thought to lead to delayed onset of cognitive impairment, but is typically followed by accelerated rate of cognitive decline; attributable to the more advanced state of neurodegeneration at the point when symptoms emerge (Stern, 2009). Aligning with this notion, sense of purpose in Project 1 predicted later onset of cognitive impairment in both samples, with more purposeful participants having larger cognitively healthy life expectancy and spending proportionally less time with MCI or dementia (see Figures 2.2 and 2.3).

Many of the lifestyle correlates of sense of purpose discussed as possible mediators of normative cognitive functioning in older adulthood may also contribute to resilience. In particular, higher education and engagement in mentally-stimulating activities are established markers of cognitive reserve (Valenzuela & Sachdev, 2006). In Project 1, sense of purpose was found to be an independent predictor of transitions across cognitive states after accounting for education, suggesting the possibility of multiple mechanistic pathways linking sense of purpose and reserve. Taken together, these findings point to sense of purpose supporting healthy cognition in mid-to-late life, allowing individuals to maintain a high level of cognitive functioning and prolonging the cognitive healthspan.

Biological Mechanisms

Worldwide, the potentially modifiable risk factors of diabetes, hypertension, obesity, physical inactivity, depression, smoking, and low educational attainment account for nearly half of the attributable risk for Alzheimer's disease (Norton et al., 2014). Project 2 demonstrated that sense of purpose predicted lower levels of allostatic load comprising several vascular and metabolic markers closely related to prominent biological risk factors, pointing to potential mediation of purpose-cognition associations through these biological systems. Considering individual biomarkers, in the HRS, sense of purpose was correlated with lower blood pressure, BMI, and levels of glycated hemoglobin, a marker used in the screening for diabetes and glycemic control. With diabetes and hypertension closely linked with increased cerebral infarction and poorer indicators of neural integrity (Arvanitakis et al., 2006; Iadecola et al., 2009), increased resilience to such conditions could mediate associations between sense of purpose and cognitive health. Sense of purpose was also found to have moderate negative correlations with depressive symptoms in both Project 1 and 2, and previous findings point to more purposeful individuals having higher education, being more physically active, and less likely to smoke (Hooker & Masters, 2016; Konkolÿ Thege et al., 2009; Pinquart, 2002). Thus, sense of purpose may promote a more positive health profile across numerous risk factors, thereby protecting against downstream risk of cognitive impairment and dementia.

More broadly, several systems involved in allostatic processes provide a direct connection between stress, functioning of peripheral bodily systems, and neural integrity. Central to allostatic responses are two systems connecting key neural regions with activation of hormonal and peripheral responses to stress: the sympathetic-adreno-medullar (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis. The SAM system is responsible for the initiation and cessation sympathetic nervous system stress response through the release of the catecholamines epinephrine and norepinephrine (Godoy et al., 2018). The HPA axis helps to mobilize physiological resources, beginning with activation of the hypothalamus in response to a stressor, producing a cascade of neuroendocrinal processes cumulating in release of the stress hormone cortisol into the bloodstream (Kudielka & Kirschbaum, 2005). When functioning properly, these complementary systems help to regulate short- and long-term physiological responses to stressors.

The hippocampus, a critical region for memory, is also central to the stress response, acting as a negative feedback mechanism to reduce HPA activity when cortisol levels are elevated (McEwen & Sapolsky, 1995). However, the density of glucocorticoid receptors in the hippocampus also leaves these neurons vulnerable to neurotoxicity resulting from chronically elevated cortisol levels (E. J. Kim et al., 2015). The loss of glucocorticoid-detecting neurons in the hippocampus further compounds issues of chronic stress by reducing the negative feedback mechanisms responsible for decreasing HPA axis activity, resulting in impaired capacity to reduce cortisol release and further impacting hippocampal integrity. In this manner, higher allostatic load can impair neurological feedback in these critical systems and lead to damage in key neural regions responsible for memory and other cognitive functions (Juster et al., 2010; McEwen & Rasgon, 2018). It is not surprising then that allostatic load is a consistent predictor of poorer adult cognitive functioning and increased prospective risk of developing cognitive impairment (D’Amico et al., 2020; Guidi et al., 2021; Matos & Souza-Talarico, 2019). Given associations between sense of purpose and allostatic load in Project 2 and in past research (Zilioli et al., 2015), lower allostatic burden may represent a mechanistic pathway linking sense of purpose with better cognitive health in older adulthood.

Trait vs. State Purposefulness

In personality psychology, there has long been a debate between the predictive utility of situational factors compared to more stable, dispositional characteristics such as the Big 5 personality traits (Fleeson, 2001). From the trait perspective, descriptive traits such as personality are useful in describing differences between individuals and in understanding behaviour and general tendencies over time (Fleeson, 2004). On the other hand, proponents of the "state" perspective argue that personality traits are poor predictors of behaviour over the short-term, and that situational contexts such as social or cognitive factors are more indicative of behavioural choices in a given situation. In this regard, while traits such as the Big 5 are strong predictors of behaviour when aggregated over the long-term, they fail to account for manifest behaviour across situations (Mischel et al., 2002). In an effort to reconcile these opposing ideologies, the Whole Trait Theory (Fleeson & Jayawickreme, 2015) describes traits as a propensity distribution of state-level behaviours. For instance, an individual high in trait extraversion may act more or less social across situations, but when aggregating these states across time, the extraverted person would be more social on average compared to someone low in extraversion.

With regards to sense of purpose in life, similar distinctions between trait and state level purposefulness could be made. Although there exists some intraindividual variability, sense of purpose is predominantly viewed as a fairly stable, trait-like characteristic in middle and older adulthood (Hill et al., 2015; Ko et al., 2016). Underscoring this point, items from the Ryff

Psychological Wellbeing Scale are framed broadly, addressing an individual's feelings of purposefulness in general (e.g., "Some people wander aimlessly through life, but I am not one of them"), rather than in the context of a specific situation or over a certain timescale. It is for this reason that sense of purpose measured with this scale is a consistent predictor of general behavioural tendencies and long-term health outcomes, but associations are less clear with outcomes across shorter timescales. In Project 3, sense of purpose did not predict cognitive performance across multiple daily EMA assessments. Though sense of purpose was assessed at the daily level, ratings were somewhat stable within-persons across time, raising questions as to whether this item was assessing true daily purposefulness or was capturing more consistent trait-level sense of purpose.

While there is a need for further EMA research to better understand the role of sense of purpose in life on everyday behaviour and functioning, it is important to consider that existing measures may not be reliable indicators of sense of purpose at the daily level. Administration of longer validated measures of sense of purpose in intensive measurement designs, though more time consuming, would facilitate more detailed evaluation of correlates of daily and within-day purpose. Moreover, there is also uncertainty regarding the multilevel factor structure of measures of sense of purpose. Given the previously mentioned lack of microlongitudinal research on sense of purpose, little is known about whether conventional measures of purposefulness are valid across shorter-term timescales. Future research using multilevel confirmatory factor analysis techniques (Geldhof et al., 2014; Rush & Hofer, 2014) on intensive measurement design data is needed to clarify the multilevel factor structure and reliability of measures of sense of purpose across short timespans.

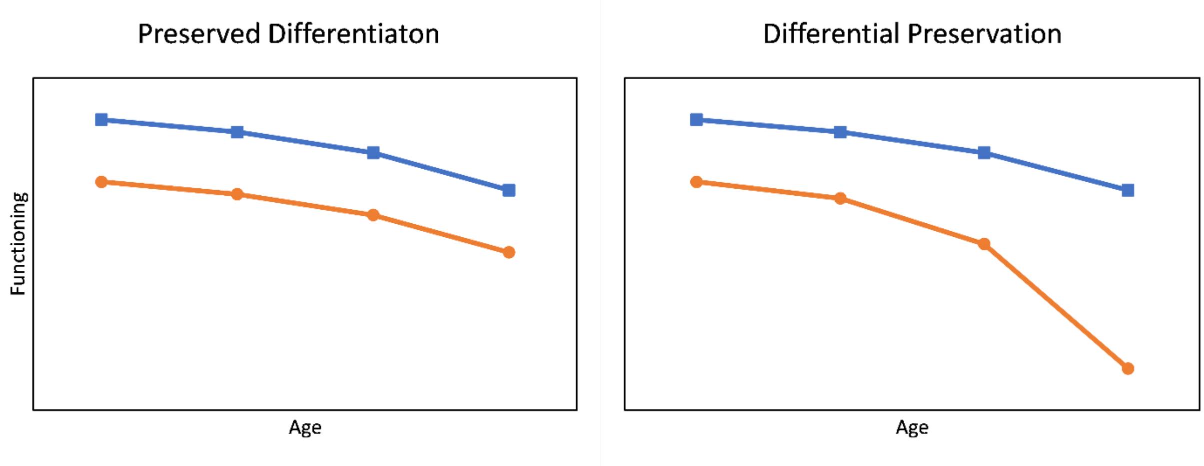
Sense of Purpose and Developmental Trajectories of Health and Cognition

These results help to address several points regarding the timing and directionality of associations of sense of purpose with health and cognitive functioning. As noted throughout this dissertation, a prominent limitation of the literature to date is that the bulk of research examines sense of purpose and markers of cognition and health using cross-sectional designs. While most of these cross-sectional studies point to more purposeful individuals showing better cognitive performance, these designs provide little insight into how such associations may develop over time. The longitudinal studies summarized in the present dissertation represent an advance on this work, providing evidence for the influence of sense of purpose on developmental trajectories of cognition and health in middle and older adulthood.

In the field of lifespan development, the impact of potential protective factors on longitudinal change is often framed in terms of two competing hypotheses: preserved differentiation and differential preservation (Bielak et al., 2014; Gow, 2020). Preserved differentiation reflects the notion that a protective factor such as sense of purpose in life accounts for persistent differences in level of functioning that are maintained across time and normative developmental trajectories. For example, in the left panel of Figure 5.1, more purposeful older adults, represented by the blue trajectory, may have consistently better cognitive performance relative to those lower in sense of purpose, with both groups demonstrating slight normative declines with increasing age. On the other hand, differential preservation (the right panel of Figure 5.1) would suggest that benefits of living a purposeful lifestyle would become progressively more impactful with increasing age, leading to divergent longitudinal trajectories in cognitive functioning across time (Salthouse, 2006).

Figure 5.1

Preserved Differentiation vs. Differential Preservation in Cognition and Health Trajectories



Interestingly, the results from the present studies lend support to both hypotheses with regards to longitudinal relationships of sense of purpose with health and cognition. In Project 2, sense of purpose was associated with preserved differentiation in allostatic load levels across multiple biomarker assessments over an eight-year period in the HRS. That is, more purposeful participants showed lower mean levels of allostatic load but did not differ in rates of change across time despite the trend of mean-level increases in allostatic load over the follow-up period. Conversely, Project 1 found that sense of purpose in life did account for differential trajectories in the progression across states of increasing cognitive impairment, with more purposeful participants demonstrating greater preservation of healthy cognitive functioning. One potential explanation for this discrepancy is that sense of purpose may confer

To this point, sense of purpose in life has been discussed as a potential driver of differences in health and cognition, however, it is important to note that associations may reflect reciprocal relationships between sense of purpose and functioning. Sense of purpose in life may be sensitive to changes in health and functioning for the same reason that having a sense of purpose is thought to facilitate health behaviours—being healthy is often necessary for many overarching life aims central to one's purpose in life (Lewis, 2020; McKnight & Kashdan, 2009).

Indeed, declining health and functioning is prominent in older adults' views on obstacles to their purpose in life, limiting their ability to engage in personally-meaningful activities and contributing to increased uncertainty regarding their future (Lewis et al., 2022). Middle-aged and older adults who suffered an incident stroke declined significantly in sense of purpose relative to their pre-stroke levels, with those perceiving poorer cognitive functioning reporting steepest declines (Lewis et al., 2020). In this way, sense of purpose may be highly sensitive to health-related changes, leading to bidirectional associations with health.

Untangling questions related to direction and causality may be particularly challenging with regards to sense of purpose and cognitive health. Sense of purpose, a higher order cognitive function, may be susceptible to early neurological changes in the long prodromal phase of dementia, accounting for prospective associations with cognitive impairment. For instance, one study in the MAP sample found evidence for bidirectional associations, with sense of purpose and global cognitive functioning predicting subsequent changes in the other variable (Wilson et al., 2013). However, sense of purpose has been found to be unrelated to post-mortem Alzheimer's disease neuropathology (Boyle et al., 2012), meaning effects of cognition on sense of purpose could be driven by other factors such as reaction to perceived cognitive decline. Future research is needed to understand the influence of health changes on sense of purpose and help support older adults compensate for health-related challenges to their goals and direction.

Conclusion

The current work provides a more nuanced examination of temporal dynamics of sense of purpose, health, and cognition relative to past cross-sectional work. An important direction for the field is to address whether sense of purpose is a stable predictor of longitudinal health or if there exist "critical periods" where sense of purpose is more impactful on health trajectories.

Though purpose has shown itself to be an important factor throughout the developmental lifespan, additional research is needed to investigate how to help individuals develop and maintain a sense of purpose in mid-to-late life. Several recent investigations have shown sense of purpose in life to be a promising target for intervention. Brief interventions involving reflection on purposeful experiences and goal setting have demonstrated potential for promoting sustained improvements in older adult sense purpose, particularly in those lowest in initial purposefulness (Chippendale & Boltz, 2015; Friedman et al., 2019). Given the downstream benefits of living a purposeful lifestyle noted throughout this dissertation, purpose-promoting interventions could enhance existing multidomain interventions (Kivipelto et al., 2018) aimed at reducing dementia risk and supporting older adult health.

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Appendix A

For project 2, models were built progressively in a stepwise fashion, with additional covariates added at each step. Below is a table displaying abridged results from preliminary ELSA models, including a sense of purpose only model (Model 1), a model with sense of purpose and demographic characteristics (Model 2), and the exploratory model with depressive symptoms and excluding sense of purpose (CESD Only model).

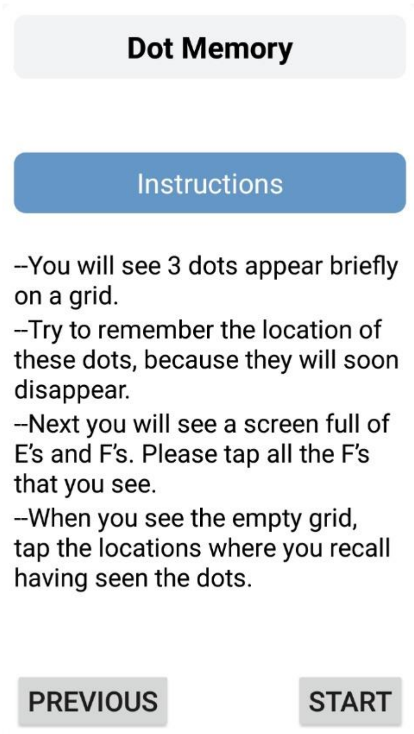
	Model 1		Model 2		CESD Only	
Parameter	Est. (*SE*)	*p*	Est. (*SE*)	*p*	Est. (*SE*)	*p*
Intercept	3.737 (.080)	< .001	3.717 (.145)	< .001	3.608 (.156)	< .001
Sense of purpose	-.238 (.082)	.004	-.205 (.090)	.022	--	
Age			.016 (.009)	.093	.018 (.009)	.052
Female			.152 (.169)	.369	.100 (.170)	.557
Education			-.168 (.182)	.365	-.212 (.177)	.230
CESD					.114 (.049)	.021
Slope	-.023 (.010)	.019	-.025 (.021)	.228	-.030 (.021)	.167
Sense of purpose	-.004 (.010)	.705	-.005 (.011)	.635	--	
Age			-.002 (.001)	.214	-.002 (.001)	.212
Female			-.015 (.021)	.487	-.015 (.021)	.481
Education			.011 (.021)	.607	.010 (.020)	.612
CESD					.004 (.006)	.524
Random coefficients						
Level-1 residual	.890 (.072)	< .001	.874 (.076)	< .001	864 (.073)	< .001
Intercept residual	1.138 (.125)	< .001	1.155 (.128)	< .001	1.178 (.128)	< .001

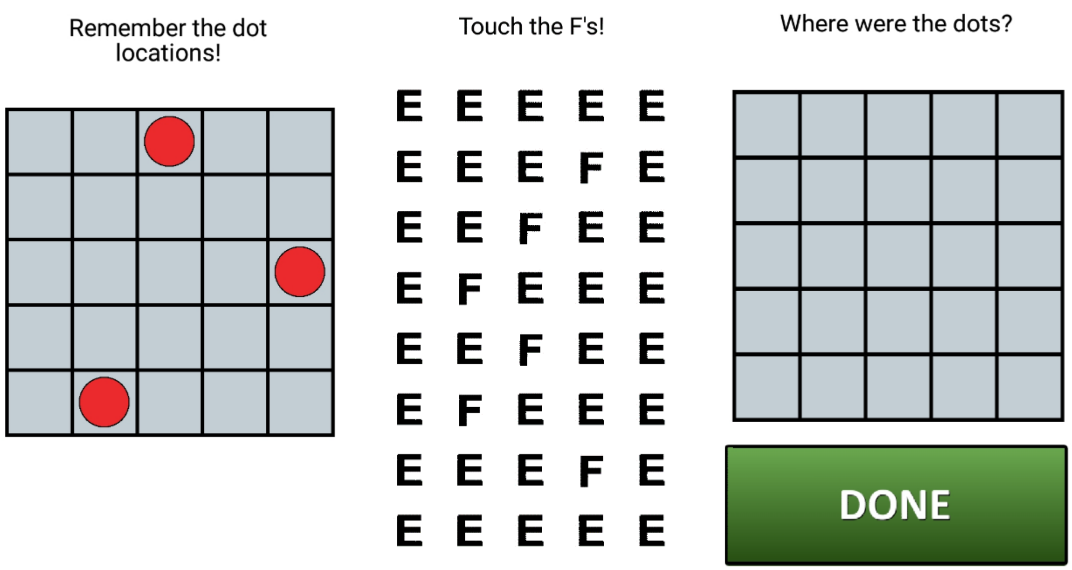
Slope residual	.000 (.002)	.846	.001 (.002)	.783	.001 (.002)	.734

Note. Est. = estimate. CESD = number of depressive symptoms on the Center for Epidemiological Studies-Depression Scale.

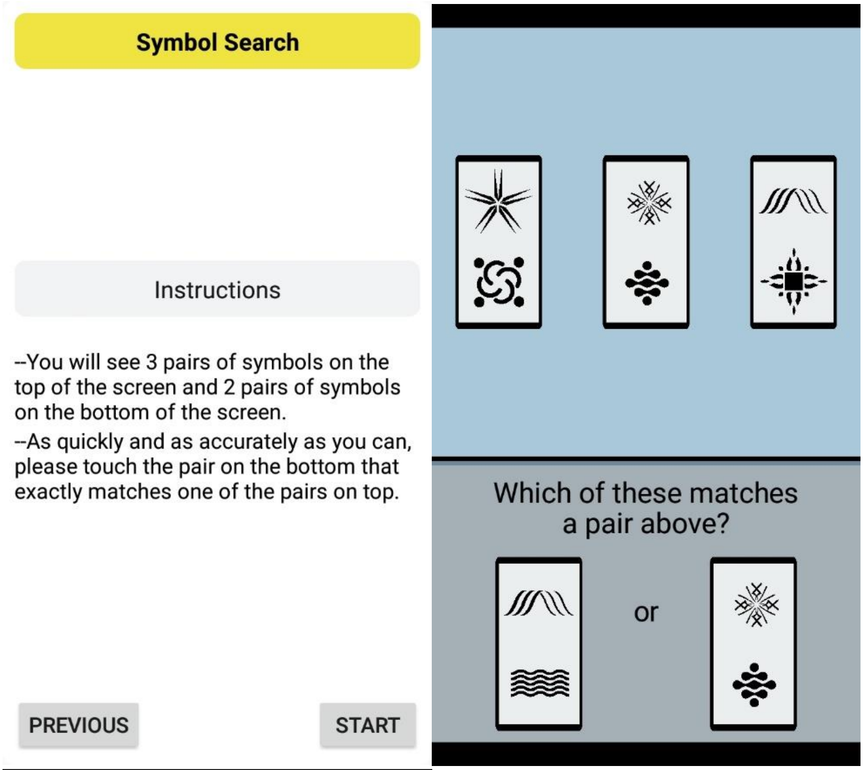
Appendix B

Dot Memory Task

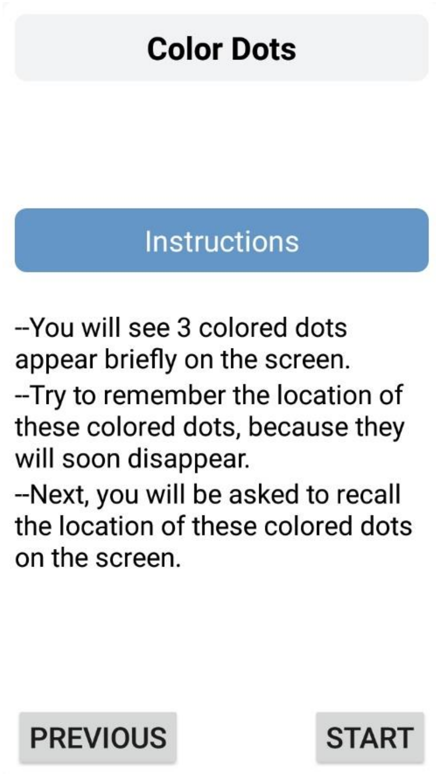


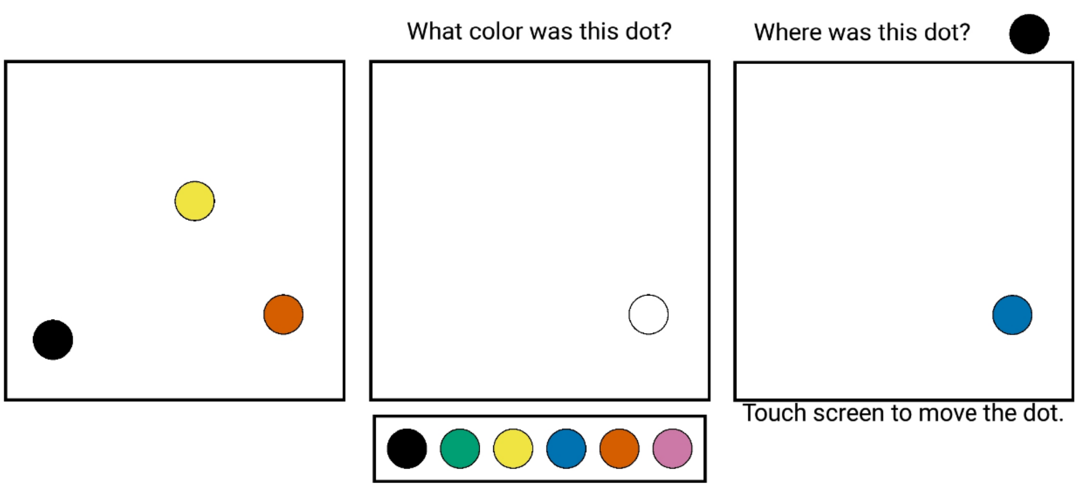


Symbol Search

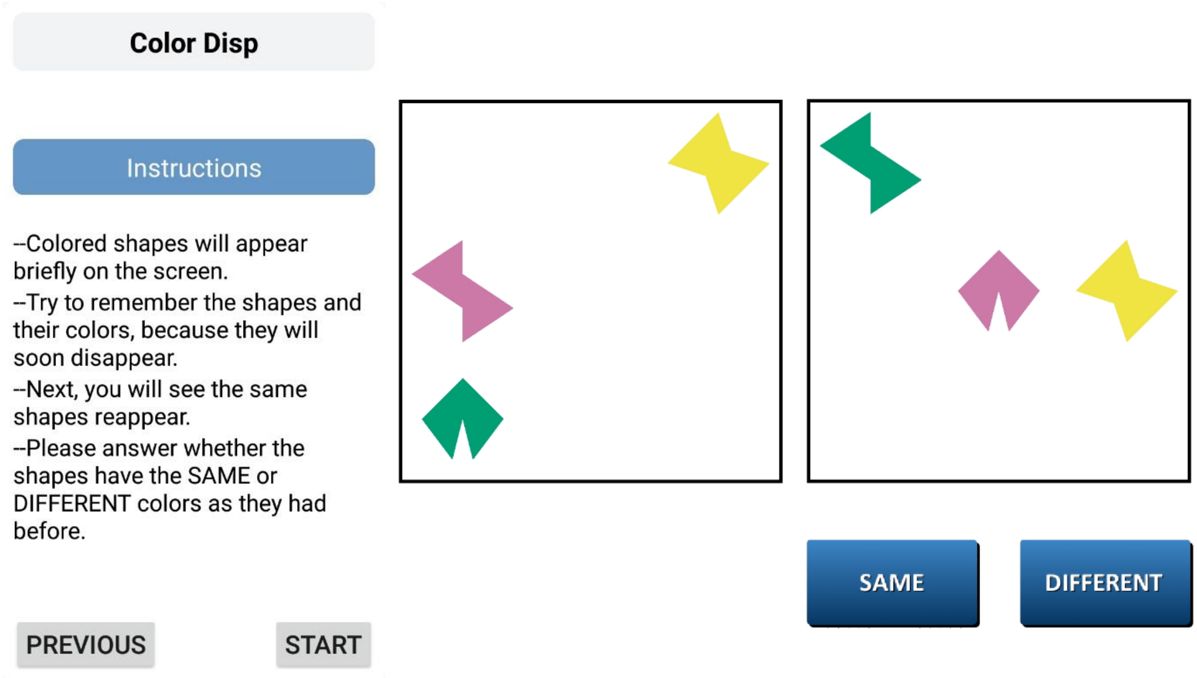


Colour Dot

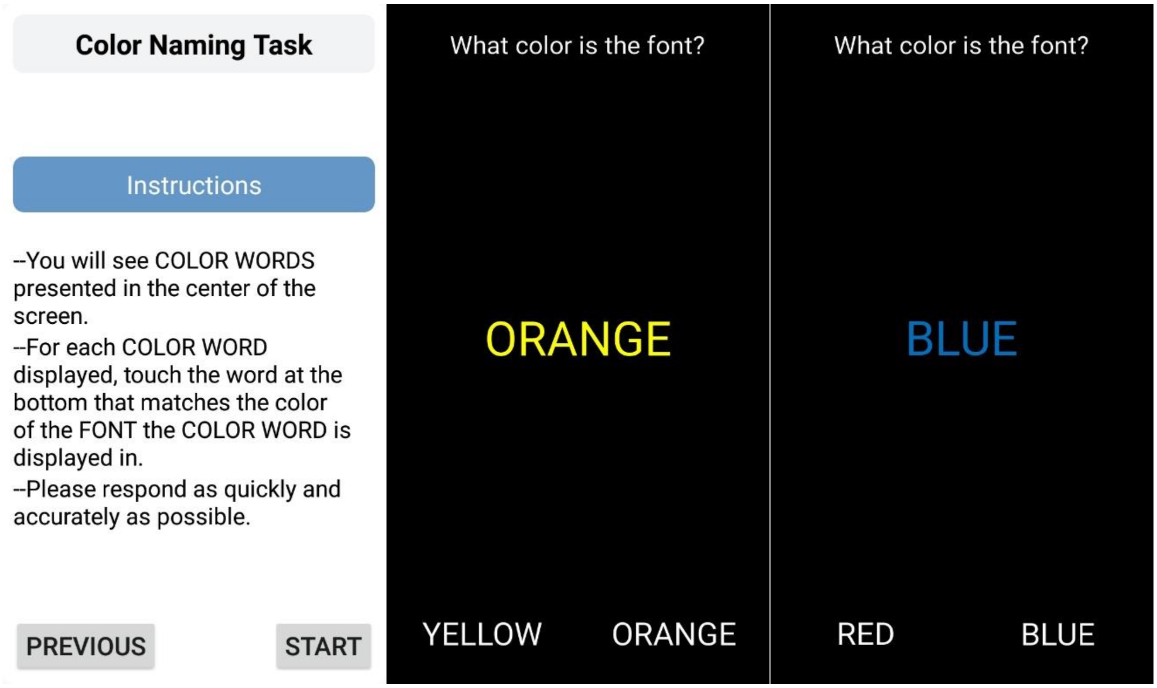

Color Dots
Instructions
--You will see 3 colored dots appear briefly on the screen.
--Try to remember the location of these colored dots, because they will soon disappear.
--Next, you will be asked to recall the location of these colored dots on the screen.
PREVIOUS
START


What color was this dot?
Where was this dot?
Touch screen to move the dot.

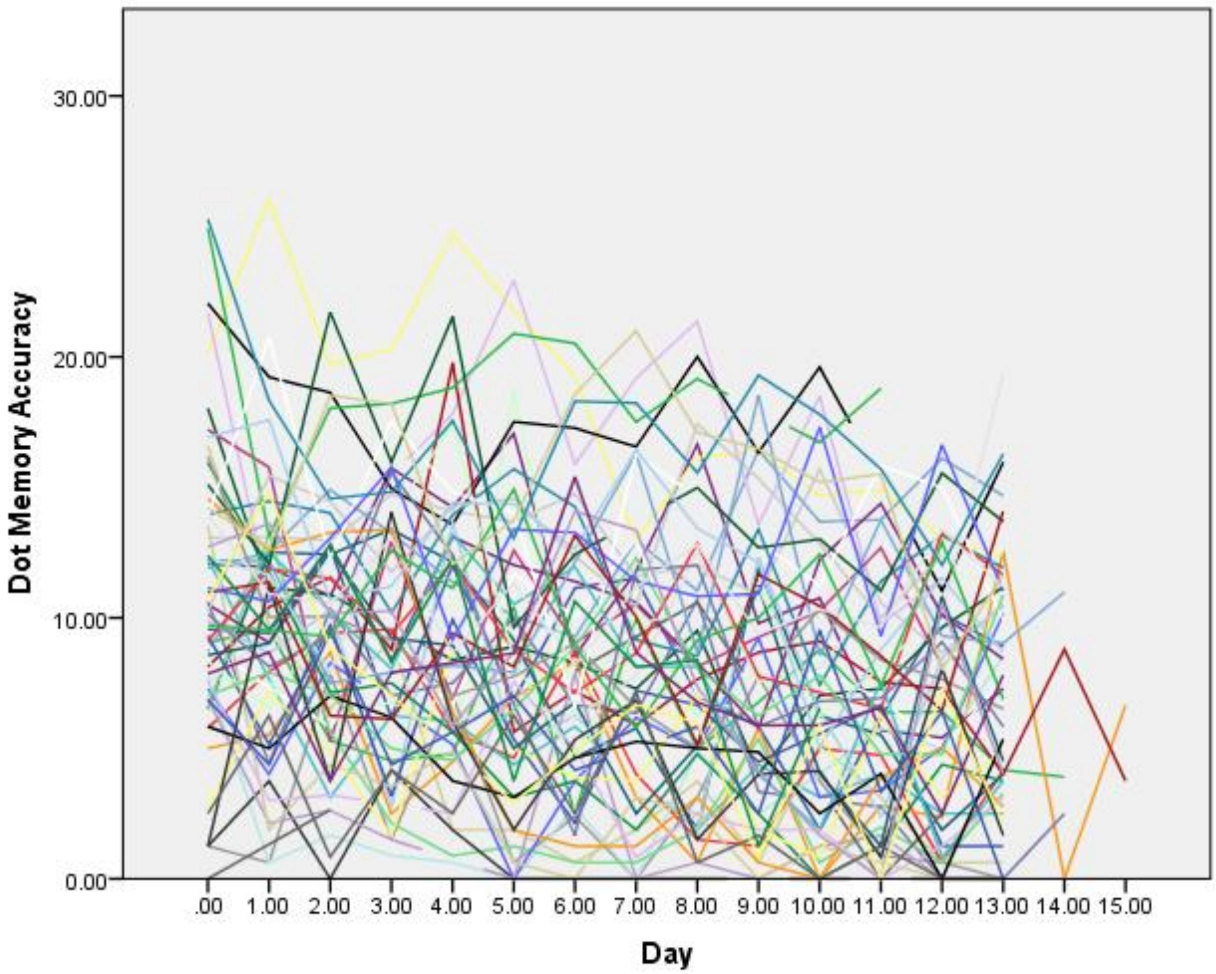
Colour Shape

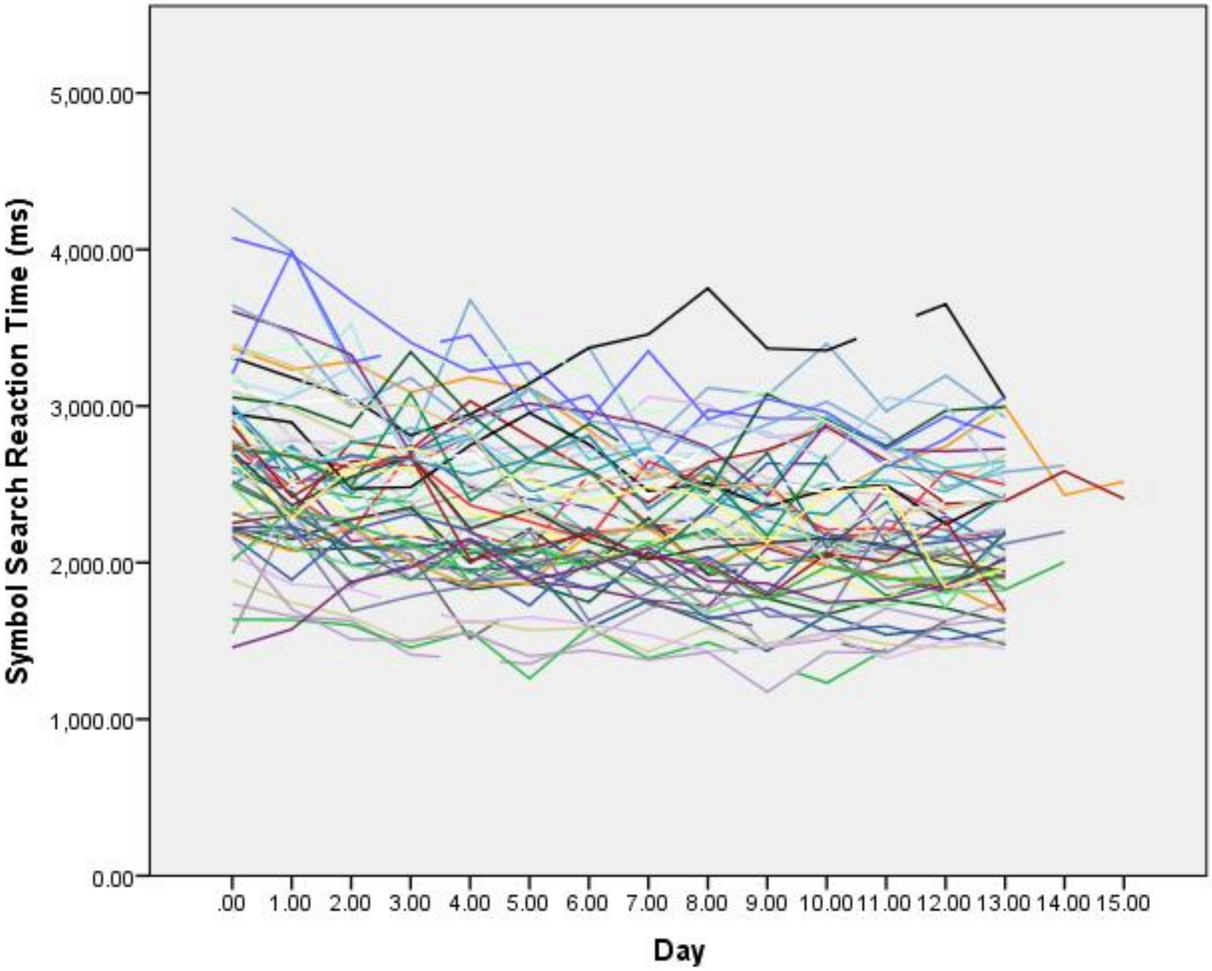


Stroop Task

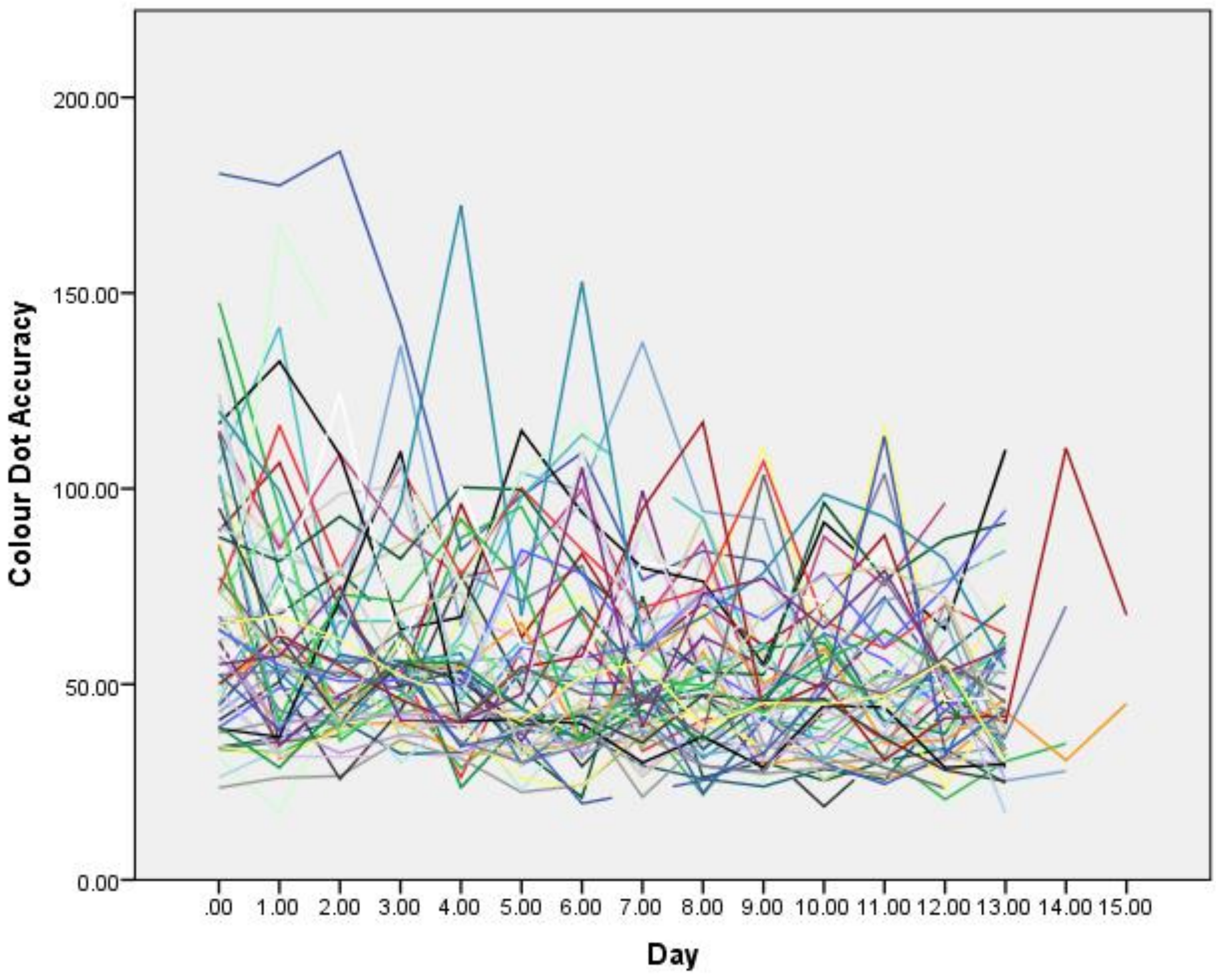

Color Naming Task
Instructions
--You will see COLOR WORDS presented in the center of the screen.
--For each COLOR WORD displayed, touch the word at the bottom that matches the color of the FONT the COLOR WORD is displayed in.
--Please respond as quickly and accurately as possible.
PREVIOUS
START
What color is the font?
ORANGE
YELLOW
ORANGE
What color is the font?
BLUE
RED
BLUE

Appendix C

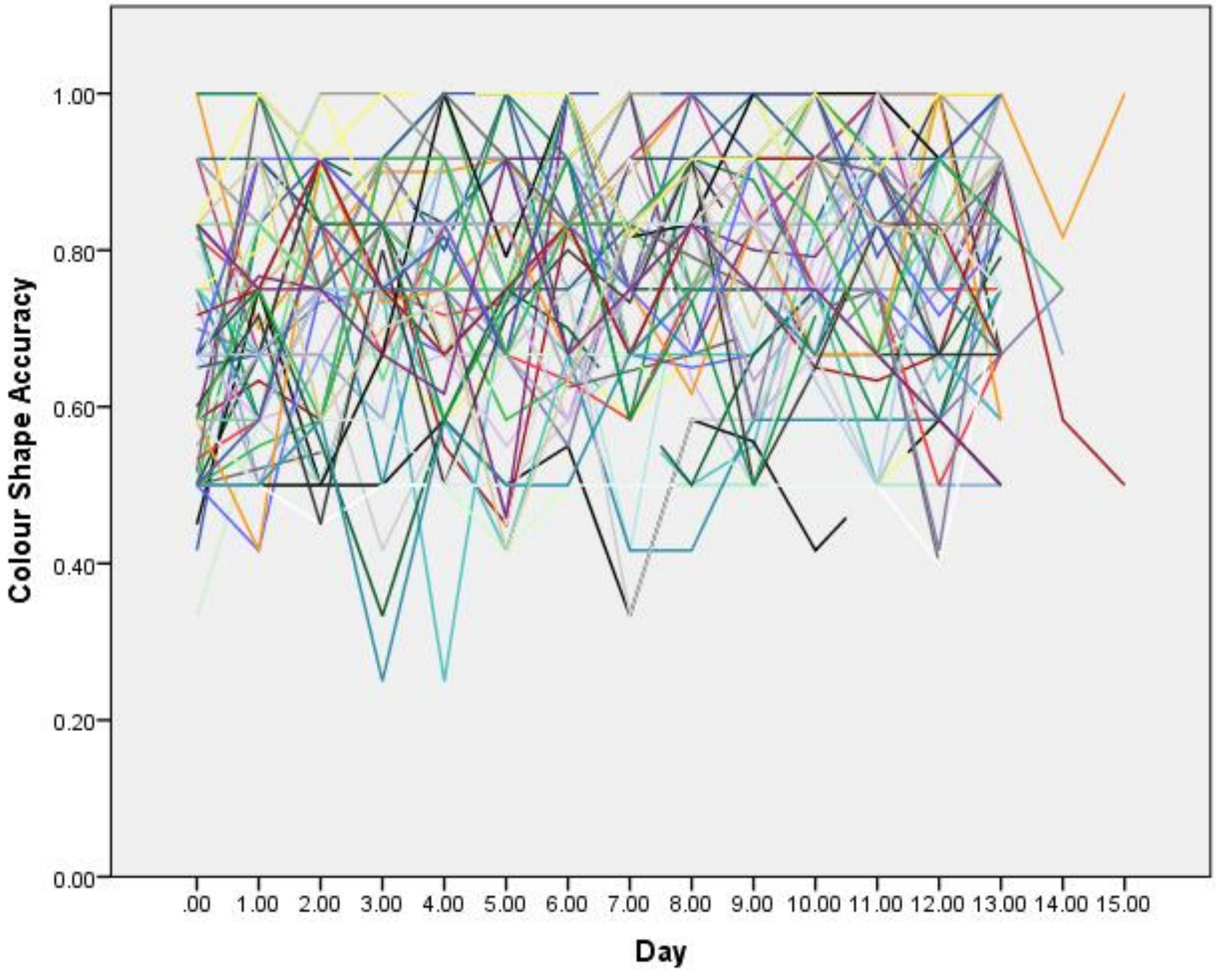

Dot Memory Accuracy
30.00
20.00
10.00
0.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
Day



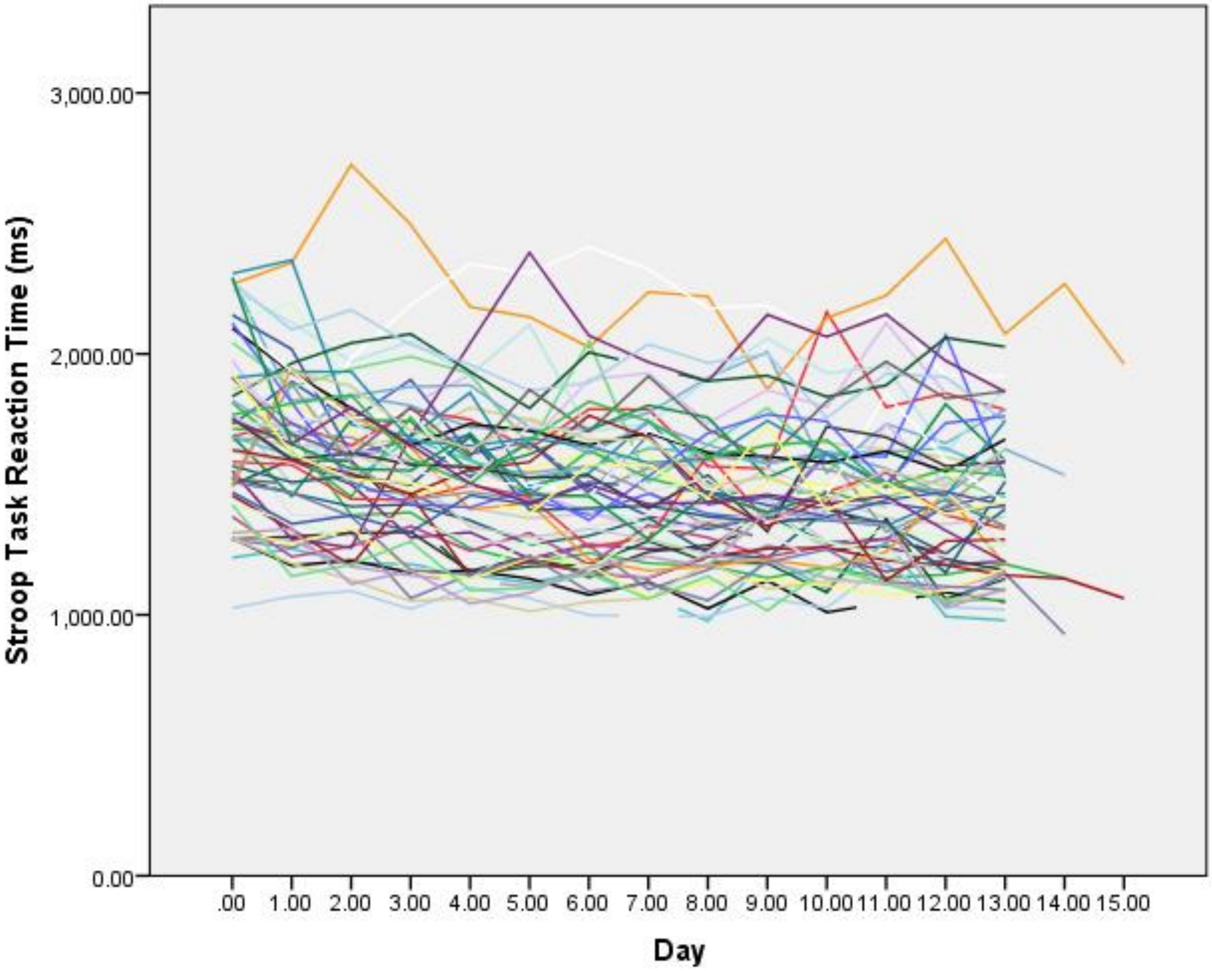
Symbol Search Reaction Time (ms)
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
Day


Colour Dot Accuracy
200.00
150.00
100.00
50.00
0.00
.00 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 14.00 15.00
Day

Colour Shape



Stroop Task


Stroop Task Reaction Time (ms)
3,000.00
2,000.00
1,000.00
0.00
.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
Day