

Unraveling the Neurocognitive Effects of Caregiver Stress Recall: An fNIRS
Investigation

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ABSTRACT

Caregiving is a rewarding and strenuous activity that affects the physiological, psychological, and cognitive processes in the human body. While caregiving stress has been studied previously, these studies have overlooked a common symptom of experiencing stress: rumination. The present study explored how recalling stressful caregiving experiences affected caregiver stress levels and their performance on a test of executive function. Neural correlates underlying cognitive performance were also examined. The findings indicate that lifetime duration of caregiving activities, not recalling stressful experiences, is associated with poorer performance on the AX-CPT, though no changes in neural correlates were observed.

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GENERAL AUDIENCE ABSTRACT

Caregiving is a rewarding activity for many individuals, but it can also be associated with many consequences like changes in mental and physical health. When these stressful moments occur, it is natural for individuals to replay them in their minds. Caregivers may experience an increase in these stressful moments, but this may impede functions in those re-playing these experiences. Caregivers frequently experience stress from their care activities, which may also lead them to recall these stressors more often. The present study examined whether thinking about stressful caregiving experiences was associated with changes in physical and cognitive changes functioning in caregivers. The results indicate that the amount of time a person spends caregiving across their lifetime, not recalling stressful caregiving experiences, is related to poorer performance on a cognitive test.

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Introduction

Care providers support individuals with many activities to promote their well-being such as helping with household management, eating and drinking, and medical care (Edemekong et al., 2023; Guo & Sapra, 2022). In the United States, the number of persons needing care is expected to supersede the available providers within the next few decades (America's Health Rankings, 2023). Among care providers, the effects of providing care are already being felt, with many reporting elevated stress levels (Ozkan Tuncay & Kars Fertelli, 2019; Sheehan et al., 2021), and mental (Huang, 2022; Kaddour & Kashita, 2020), physical (Leggett et al., 2016, Leggett et al., 2015, Correa et al., 2015), and health-related symptoms (Capistrant et al., 2012a; Capistrant et al., 2012b; Jian et al., 2022). Caregivers of older adults particularly report these symptoms (Schulz et al., 2016). Among other consequences, care providers report alterations in their cognitive functioning, including memory and attentional decline, which are used in their everyday caregiving activities (Caswell et al., 2003; Oken et al., 2011). These alterations are associated with experiencing varying levels of stress and are a key factor in clinical disorders such as posttraumatic stress disorder (PTSD) (Maeng & Milad, 2017).

Persons who experience trauma are similar to care providers as both groups experience acute and chronic stress (Maeng & Milad, 2017). One symptom of stressful experiences is the symptom of "rethinking," which is referred to as "re-experiencing" in PTSD literature and "rumination" in caregiving literature (Michael et al., 2007). Although research has examined this phenomenon (hereby referred to as "rethinking") in clinical populations of persons with PTSD, it remains underexamined in care providers. Rethinking is associated with mental and physical consequences such as anxiety and depression and alterations in cardiovascular response (Hayes et al., 2012; McFarlane, 2010). However, memory and executive function (EF) performance (i.e.,

attention, cognitive control, and inhibition) have also been found to decrease in stressed populations like persons diagnosed with PTSD (Mathew et al., 2022; Schweizer & Dangleish, 2011; Saunders et al., 2015; Verwoerd et al., 2009) and caregivers (Chen & Botticello, 2013; Correa et al., 2015; Correa et al., 2016; Mackenzie et al., 2007; Mackenzie et al., 2009; Mahoney, 1998; Oken et al, 2011; O’Sullivan et al., 2018; de Vugt et al., 2006).

The present study examined how recalling stressful caregiving experiences is associated with alterations in EF using behavioral and neural correlate measurements. Specifically, the study sought to answer three research questions:

- 1) Does recalling caregiving experiences increase participants’ self-reported stress?
- 2) Do caregivers perform worse on an executive function task after completing an interview about stressful caregiving experiences relative to caregivers who complete an interview about a neutral topic, such as their hobbies?
- 3) Do caregivers who participate in the caregiving stress interview demonstrate reduced prefrontal cerebral perfusion while completing the executive function task?

To date, no study has examined rethinking in caregivers using behavioral and neurophysiological approaches. Previous research on stress response in caregiving populations has identified physiological, psychological, and cognitive consequences among those facing both acute and chronic stressors. Findings from the present study provide insight into the effects of reliving a stressor on caregivers’ physiological and cognitive functions. Specifically, the present study found that a relationship between lifetime caregiving activities and EF performance. The study also informs researchers of future directions to examine in the context of stress recall in caregivers.

In the following chapters, readers will learn about caregiving and its rewards, challenges, and outcomes. In Chapter 1, previous literature examining caregivers and stress-related outcomes will be discussed, especially in the context of stress recall. The current study and its hypotheses will also be introduced in this section. In Chapter 2, the study's methodology will be presented, detailing recruitment, measures utilized, and steps taken to clean the data. This includes a discussion of the AX-Continuous Performance Task (AX-CPT) and functional near-infrared spectroscopy (fNIRS), the behavioral and neurophysiological measurements used in this study. In Chapter 3, the results will be presented, including answers to the research questions and hypotheses described in Chapter 1. A detailed examination of post hoc research questions and analyses will also be presented here. Chapter 4 presents a discussion of the research findings, as well as recommendations for study improvements and future directions.

Chapter 1: Literature Review

Caregivers and Care Providers

Care roles are multidimensional, involving the physical, mental, emotional, and social health activities of the care recipient. Hermanns (2012) describes the care process as a holistic process that is facilitated by the traits, emotions, skills, knowledge, and time of the person providing the care. The roles that these individuals take are often subcategorized. For instance, individuals are categorized as “formal” and “informal,” which primarily refer to how they provide care to the recipient. “Formal” providers are typically individuals or entities that have received some sort of formalized training and receive compensation for their care responsibilities (Johns Hopkins, 2024). “Informal” caregivers, however, typically provide care without monetary transaction and tend to be personally acquainted with the recipient (Johns Hopkins, 2024).

Caregivers and care providers may also be identified according to the diagnosis or ailment of

their care recipient. For example, caregivers of persons diagnosed with dementia or Alzheimer's Disease are largely referred to as Alzheimer's Disease (AD) and Alzheimer's Disease and Related Dementia (ADRD) caregivers (Elmstahl et al., 2018). Previous research has focused on caregivers of persons diagnosed with AD or ADRD (hereafter collectively referred to as ADRD) to examine the chronic effects of caregiving for both the caregiver and the care recipient. Other literature has utilized caregivers of people diagnosed with physiological (cancer, stroke) and psychological (schizophrenia, depression, psychotic) conditions. These categorizations aid in contextualizing the different care activities being provided as certain diagnoses are associated with different types of activities and intensities (Brodaty et al., 2014; Elmstahl et al., 2018).

Regardless of their role, caregivers and care providers aid their recipients in maintaining their health and well-being, which are often broken down into tasks referred to as activities of daily living (ADLs) and instrumental activities of daily living (IADLS). ADLs include skills that are fundamental for maintaining health such as eating, bathing, and mobility (Edemekong et al., 2023), whereas IADLs are personal functions required to sustain independent living like managing finances, completing housework, and participating in personal hobbies or interests (Guo & Sapra, 2022). The needs of recipients often change over time and differ depending on the care recipient's condition. For example, care recipients diagnosed with ADRD typically require more intensive care and longer durations of care, as these conditions are progressive and may span a decade (or more) in length (Jutkowitz et al., 2020; Mayo Clinic, 2023). Specifically, functional memory loss, EF difficulties, and attentional changes are common in care recipients with ADRD (Xu et al., 2019; Erberk Ozen & Rezaki, 2007). These alterations may challenge their abilities to maintain personal care, household maintenance, and other necessary activities for their lifestyle and well-being (Jutkowitz et al., 2020). Thus, as the capabilities of care

recipients diminish, caregivers and care providers are likely to face additional hours of care and provide a greater number of care activities to support their recipients.

Caregiving Prevalence

The number of individuals providing care to older adults is steadily increasing, especially for those providing informal or unpaid care (Giovannetti & Wolff, 2010; AARP, 2020). Between 2015 and 2020, 1 in 5 Americans (~ 53 million adults) actively provided informal care to an older adult (AARP, 2020). During this same timeframe, 4.5 million paid caregivers (i.e., nurses, direct care workers, and other service providers) also provided care to older Americans (AHIP, 2020). More specific estimates suggest that among older adults receiving help with daily activities, at least 90% receive some form of informal care (Freedman and Spillman 2014; Kaye et al., 2010; Spillman 2009; Spillman & Black 2005).

Throughout the U.S., formal care networks and healthcare systems are already struggling to meet the needs of millions of older adults, especially in larger cities where overall care needs are greater (America's Health Rankings, 2023). In New York, for example, it is estimated that for every 1,000 adults aged 65 and older, only 137.6 care workers are available to fulfill their needs (America's Health Rankings, 2023). With the rising number of individuals reaching older adulthood in the U.S., concern about whether care networks are sufficient to meet these expanding needs is prevalent. This concern is attributed to advancements in medical sciences that improve at-home wellness and recovery (i.e., shorter hospital stays and chronic disease management) and lengthen the average human lifespan (Talley & Crews, 2007). However, these medical advances are also associated with medical staffing shortages, increases in hospital and other medical costs, and a greater need for long-term care (Talley & Crews, 2007). The demand for ADRD care workers is expected to rise as the number of people diagnosed with ADRD is

expected to increase from nearly 7 million in 2024 to over 13 million by 2050 (Alzheimer's Association, 2023). These numbers are also expected to rise among older adults with low-income statuses (Scommegna & Sherburn, 2022).

To address the care gap, family and friends have assumed a caregiver role (Schulz & Czaja, 2018), comprising over 50 million informal care providers in the U.S. (AARP, 2020). However, both caregivers and care recipients continue to report unmet needs (Black et al., 2013; Hwang et al., 2003). For example, in a sample of community-residing persons with ADRD and their caregivers, 99% of persons with ADRD (N = 254) and 97% of their caregivers (N = 246) reported at least one or more unmet needs (Black et al., 2013). The most common needs that were cited include increasing safety measures (persons with ADRD) and available resources (caregivers). Older adults with disabilities (Beach & Schulz, 2017) and older adults with advanced cancer diagnoses (Hwang et al., 2003) also report at least one unmet need for both care recipients (Beach & Schulz, 2017) and caregivers (Hwang et al., 2003). In Beach's (2017) sample, care recipients reported needing more help performing ADLs like changing out of wet or soiled clothing, and IADLs like managing medications and assistance with mobility. Caregivers in Hwang's (2003) sample reported needing additional educational resources and training. These care challenges will likely be reflected in the number of monthly hours of care for recipients, with some researchers estimating an increase of at least 100 hours per month (Beach & Schulz, 2017).

Caregiver Demographics

Understanding caregivers is essential to understanding their needs. Research on carers, both formal and informal, indicates that middle-aged women are often identified as the primary people providing care to older adults. Estimates place women, typically around the age of 49

(AARP, 2020; Family Caregiver Alliance, 2016; National Alliance for Caregiving, 2015), as making up 57-81% of all caregivers in the US (for review, see Sharma et al., 2016). However, the number of male caregivers (Akpinar et al., 2011; Bookman & Kimbrel, 2011) and caregivers over the age of 65 years (Sharma et al., 2016) has steadily increased, with some studies reporting a rise in the number of male caregivers in the U.S. (Akpinar et al., 2011; Bookman & Kimbrel, 2011).

Several factors provide insight as to why caregivers tend to be women within the U.S. Some explanations are situated in patriarchal ideologies, while others refer to attributes that are ‘naturally found’ in women (i.e., being “nurturing” or a “natural caregiver”) (Hammond-Collins et al., 2014; Sharma et al., 2016). Thus, women are more likely to fall into this role due to perceptions of their upbringing and the larger society in which they are raised. Some literature also draws on women being less likely than men to hold jobs outside of the home, making them more available to take on caregiving roles. (Papastavrou et al., 2009; Lin et al., 2011). However, the increase in the number of men assuming a caregiver role may be explained by the growing number of women assuming careers outside of the home. However, this may also be associated with the overall increase in care needs for older generations (America’s Health Rankings, 2023).

Race and ethnicity characteristics of U.S. caregivers vary by source. For example, Anderson (2013) reports caregivers as primarily non-Hispanic Black individuals, whereas the National Caregiving Alliance and AARP (2015) report caregivers as primarily white (62%) or Hispanic (21%). More recently, AARP (2020) reports non-Hispanic, white persons as the most prevalent group providing care. Strengthening the accuracy of these findings is imperative to ascertain the most reliable experiences of caregivers and their recipients, especially as cultural

differences may influence their experiences and outcomes (Ejem et al., 2018; Tran et al., 2023; Whitney et al., 2023).

The Effects of Caregiving on Caregivers

Caregivers report a variety of benefits associated with caregiving including higher self-efficacy, self-esteem, and competency ratings (Kim et al. 2016; Saban 2016), with more positive well-being also reported among African American and Hispanic caregivers (Pinquart & Sorenson, 2005). Caregivers also endorse having closer relationships with their care recipients (Haley et al., 2009) and experiencing lower levels of stress and burden (van der Lee et al., 2014). However, caregiver experiences are highly individualistic, and the beneficial effects of caregiving are not always reported (Revenson et al., 2016; Schulz & Monin, 2012). Some research suggests that differences in caregiver experiences are associated with their *own* perception of the benefits and consequences of caregiving (Mackenzie and Greenwood, 2012). Pendergrass (2018) conceptualizes this by thinking of the benefits and consequences of caregiving as two points on a single continuum, with caregivers experiencing both simultaneously.

Caregiving and its activities are also consistent with the hallmarks of a chronic stressor (Brown et al., 2014; Vitaliano et al., 2003), and are characterized by psychological and physiological strain that tends to persist over time (Brown et al., 2014; Vitaliano et al., 2003). This strain is often coupled with additional secondary stressors, which refer to stressors that occur outside of caregiving, including family conflicts and work challenges (Brown et al., 2014). Due to its nature, caregiving stress has also been used as a conduit to examine long-term stress effects in humans (Vitaliano et al., 2003; Whittaker & Gallagher, 2019). These include many domains of health and well-being but prominently include aspects of physiological health like

immune system functionality (Kiecolt-Glaser et al., 2010), bodily hormone responses (Leggett et al., 2016), and cardiovascular responses (Capistrant et al., 2012a; Capistrant et al., 2012b).

The Physiological Effects of Caregiving on Caregivers

The physiological health of caregivers has been examined using a variety of measures like self-assessment of health and well-being, physiological health status (health markers, adherence to health behaviors), and mortality. Among their findings, experts acknowledge the positive influences of caregiving activities on caregiver outcomes such as its influence on daily physical activity and physical health, which are reported to be increased compared to non-caregivers (Fredman et al., 2006; Talley & Crews, 2007). However, at least some caregivers are at risk for adverse health outcomes (Capistrant, 2016), and this can outweigh the benefits that have been reported (Schulz & Eden, 2016).

Physiological health outcomes are influenced by contextual elements like a person's genetics and environment (Hernandez et al., 2006; Woolf et al., 2013). Other individual characteristics can affect these outcomes as well, such as socioeconomic status (SES), health habits, and histories of prior illness (Brown & Brown, 2014; Robison et al., 2009; Roth et al., 2015; Schulz & Sherwood, 2008). Specific patterns have emerged from work examining these factors in caregivers. Increased cortisol (Leggett et al., 2016, Leggett et al., 2015, Correa et al., 2015) and inflammation markers (Kiecolt-Glaser et al., 2010; Gouin et al., 2012) were found in caregivers of people with ADRD relative to non-caregiving controls. These elevations were also found to persist over time (Kiecolt-Glaser et al., 2003; von Kanel et al., 2012; Rohleder et al., 2009), and were associated with accelerated aging of the immune system, specifically telomere erosion (Damjanovic et al. 2007), and increased risk of coronary heart disease (Capistrant et al., 2012a; Haley et al., 2010; Mausbach et al. 2007; von Känel et al. 2008).

Although beneficial effects of caregiving have been found in the context of health behaviors, these become muddled when examining conflicting study results. Although some studies have observed increased physical activity by caregivers (Fredman et al., 2006), many others have observed increased engagement in negative health behaviors like smoking (Reeves et al., 2012), eating poorly (Reeves et al., 2012), and forgoing preventative health screenings (Berkman et al., 2011). Demographic factors like race (Rabinowitz et al., 2007; Berkman et al., 2011) and socioeconomic status (Brown & Brown, 2014; Robison et al., 2009; Roth et al., 2015; Schulz & Sherwood, 2008) and care-related factors such as the intensity of care provided (Burton et al., 1997), may help explain this inconsistency. However, poorer health behaviors and lower self-rated physical (Pinquart & Sorenson, 2003) and mental (Trivedi et al., 2014) health remain consistent throughout caregiving literature.

Perhaps one of the most concerning issues is determining the extent to which caregiving activities lead to altered mortality rates in caregivers. This association is unclear and may depend on individual characteristics and context. In some population-based studies, caregiving is associated with lower mortality risk compared to non-caregivers (Roth et al., 2015; Fredman et al., 2010; Roth et al., 2013; Brown et al., 2009, O'Reilly et al., 2015; Ramsay et al., 2013; O'Reilly et al., 2008). However, this contradicts other evidence that establishes a connection between caregiving and higher mortality rates among caregivers compared to both non-caregiving controls (Perkins et al., 2013; Schulz & Beach 1999) and lower-stressed caregiver controls (Roth et al., 2015, Roth et al., 2013). Caregiver stress responses may help explain these findings. For example, caregiving literature reports low to moderate strain resulting from participation in caregiving activities, with far fewer reports of high strain (Roth et al., 2015; Roth et al., 2013). However, many of these studies include broader populations of caregivers that

report varying levels of strain. Thus, persons reporting high levels of strain are often overshadowed by the greater number of caregivers reporting lower levels (Roth et al., 2015; Roth et al., 2013), which may skew these results.

Stress responses can also precede alterations in cardiovascular health and well-being in caregivers (Capistrant et al., 2012a; Capistrant et al., 2012b; Jian et al., 2021). Systems specifically impacted by these responses are the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic adrenal medullary (SAM) systems (Sapolsky, 1999; Thierry et al., 1968). Housed within these systems is the fight-or-flight response which utilizes stress hormones (e.g., cortisol, norepinephrine, epinephrine) to attenuate stress stimuli received by the body (Bidwell et al., 2021). When these hormones are present, changes in cardiovascular processes commonly occur, which facilitates first-order and downstream effects (Jian et al., 2021). First-order effects found in caregiving populations include increases in blood pressure (BP) (spousal caregivers) (Capistrant et al., 2012b), downstream effects of synaptic growth (acute stress) (Lupien et al., 1998; Litzelman et al., 2014), and lower grey matter volume in the prefrontal cortex and hippocampus (chronic stress) (Gianaros et al., 2007). Because these systems rely on each other and often respond to changes in one another, aging and caregiving experts postulate how these associations are connected to the multifaceted changes seen in caregivers across their caregiving experience. This is especially of interest when examining the relationship between physiological stress and affective and mental health outcomes in caregivers.

The Affective and Mental Health Effects of Caregiving on Caregivers

Caregivers often report experiencing elevated levels of burden and stress relative to their non-caregiving counterparts (Ozkan Tuncay & Kars Fertelli, 2019; Sheehan et al., 2021). This

phenomenon, which is commonly referred to as “caregiver burden,” encompasses the physical, emotional, and mental exhaustion a caregiver may experience as the result of providing care to another person (Gérain & Zech, 2019; Thompson et al., 2014). Much of the literature examining the psychological consequences of caregiving utilizes burden as an outcome, with specific symptoms (e.g., depression and depressive symptomology, anxiety and anxious symptomology, and subjective well-being) as factors intermixed within the relationship. For example, Del-Pino-Casado (2019) examined anxiety and depression rates across caregivers of care recipients with varying conditions. Among their findings, caregivers of people diagnosed with ADRD or who experienced a stroke reported the highest rates; 40.2% of caregivers of people who experienced a stroke reported experiencing symptoms of depression while 21.4% reported experiencing symptoms of anxiety. Caregivers of people diagnosed with ADRD reported lower rates of depression symptoms (34.0%), but higher rates of anxiety symptoms (43.6%). Similar rates of depression and anxiety were found previously by Sallim (2015) (34% & 44% respectively) in caregivers of persons with ADRD and more recently by Kaddour & Kashita (2020) (anxiety: 32.1%) and Huang (2022) (47% experienced depression or anxiety symptoms) in the same population.

In follow-up studies, Del-Pino-Casado (2019, 2021) reported similar patterns in caregiver anxiety and depression rates even after controlling for common recipient covariates (i.e., functional, behavioral, and psychological symptoms and cognitive impairment), and caregiver covariates (i.e., intensity of care). The relationship between caregiver burden and anxiety symptoms revealed positive associations across all but one study included in the meta-analysis ($N = 75$), with a combined effect of $r = 0.51$ (95% confidence interval [CI] = 0.47; 0.54) (Del-Pino-Casado et al., 2021). Additionally, caregiver burden and depressive symptomology were

positively associated across a sample of 51 studies ($r = 0.514$; 95% CI = 0.491, 0.550), with a larger effect present in caregivers of people with ADRD relative to caregivers of frail older adults and stroke survivors (Del-Pino-Casado et al., 2019).

Some concern has been raised about the validity of these findings over time. Some literature reports anxiety (Hwang et al., 2023; Pucciarelli et al., 2018) and depression (Pucciarelli et al., 2018) symptomology as decreasing over time, but other studies have countered this finding. For example, Haines (2015) assessed longitudinal rates of depression in caregivers and found that these reports remained relatively consistent at one-year (29%) and two-year (31.9%) follow-ups. Further, studies assessing anxiety across time have found little differences in caregiver anxiety rates between cross-sectional and longitudinal studies (Del-Pino-Casado et al., 2021). Explanations for this discrepancy generally centered around study covariates such as age, gender, and income (for a review, see Choi et al., 2012). However, it remains that caregiving activities are associated with changes in caregiver affective states and mental health, especially anxiety and depression.

The Cognitive Effects of Caregiving on Caregivers

Cognitive functions rely on cortical structures and receptors to send and receive information. These sites house cortisol receptors, a hormone implicated in the stress response. This hormone has also been implicated in changes in cognitive processes when altered (Romero-Martinez et al., 2018). However, concentrations of these receptors differ among cortical areas, thus their processes may be differentially affected (Kyme, 2006; Lupien et al., 1998; Stawski, et al., 2011). With established connections between stress and cognition, is understandable why scholars are interested in examining cortical structures and their underlying processes in

caregivers, a unique population of individuals who experience acute and chronic stress in their everyday lives.

Global Cognition. Caregiver cognitive performance has been examined cross-sectionally and longitudinally but has yielded inconsistent findings. While some studies suggest pronounced cognitive decline in caregivers (Romero-Martinez et al., 2018; Pertl et al., 2015), others do not (Correa et al., 2016; Mallya & Fiocco, 2018). For example, informal caregivers participating in care activities for longer durations of time experienced greater cognitive decline during and after cessation of their caregiving activities (Romero-Martinez et al., 2018) and across a 2-year time period (Vitaliano et al., 2009). Similar findings have been published that support more pronounced cognitive decline in both male and female caregivers of people with ADRD (de Vugt et al., 2006; Lee et al., 2004; Pertl et al., 2015; Vitaliano et al., 2009; Vitaliano et al., 2017). However, no difference between caregiver and control groups was found by Correa (2015, 2016), Dassel (2017), and Mallya (2018) along with several others (O'Sullivan et al., 2018; Palma et al., 2011). This finding also occurred in a longitudinal study, which examined these differences across a 6-year timespan (Dassel et al., 2017). The discourse between these findings may be due to sample characteristics such as gender and sample size, as non-significant results were more common in studies utilizing smaller sample sizes or when results were analyzed by gender (de Vugt et al., 2006; Lee et al., 2004; Pertl et al., 2015; Vitaliano et al., 2009; Vitaliano et al., 2017).

Memory. Apart from global functioning, researchers have also examined facets of memory including working (Chen & Botticello, 2013; Correa et al., 2015; Mackenzie et al., 2007; Mackenzie et al., 2009; Mahoney, 1998; O'Sullivan et al., 2018), visuospatial/verbal (Lathan et al., 2016; Mackenzie et al., 2007; Mackenzie et al., 2009; O'Sullivan et al., 2018),

declarative (de Vugt et al., 2006; Chen & Botticello, 2013; Lee et al., 2004; Mackenzie et al., 2007; Mackenzie et al., 2009; Mallya & Fiocco, 2018), and episodic (Bhattacharyya et al., 2023; Caswell et al., 2003; Correa et al., 2016; Oken et al., 2011). Broadly, mild, everyday stress and caregiving burden are associated with small memory failures like forgetting one's house keys or taking medication (Mahoney, 1998). However, more chronic forms of stress and burden are linked to impairments in episodic memory, and learning (Caswell et al., 2003; Oken et al., 2011). When attuning to these domains specifically, visuospatial memory and verbal information performance did not differ significantly (Mackenzie et al., 2007; Mackenzie et al., 2009; O'Sullivan et al., 2018) though poorer performance was observed in a sample of caregivers of persons with ADRD (Lathan et al., 2016). Episodic memory findings were more straightforward, with caregivers of persons with ADRD performing the same (Correa et al., 2015; O'Sullivan et al., 2018) or worse (Correa et al., 2016) than non-caregiving controls. Longitudinally, episodic memory performance has been positively associated with caregiving, such that caregivers perform better on episodic memory tests than their non-caregiver counterparts across a 10-year time period (Bhattacharyya et al., 2023). For declarative memory performance, caregiver performance patterns were more similar, with most studies finding poorer performance for caregivers of persons with ADRD or stroke, and among palliative care caregivers (de Vugt et al., 2006; Lee et al., 2004; Mackenzie et al., 2007; Chen & Botticello, 2013; Mackenzie et al., 2009) and fewer finding no significant differences in memory performance (Mackenzie et al., 2009; Mallya & Fiocco, 2018).

Executive Function. Another area of the brain ripe with cortisol receptors is the prefrontal cortex (PFC), which primarily houses EFs like attention, working memory, and inhibitory control (Viho et al., 2019). Studies examining these processes in caregivers have

demonstrated differences in these functions. Attention and digit-related working memory tasks were associated with faster response times, but also more errors, in caregivers compared to controls (Mackenzie et al., 2007; O’Sullivan et al., 2018). Additionally, digit working memory performance was poorer relative to controls (Chen & Botticello, 2013; Correa et al., 2015; Mackenzie et al., 2009).

Performance on interference control and processing speed tasks were more heterogeneous, with results often dependent on specific factors like caregiver demographic characteristics (i.e., age, education), caregiver health status, and sample size (García-Castro et al., 2022). For example, in caregivers of people diagnosed with ADRD or Parkinson’s Disease, EF was negatively associated with perceptions of role overload and care intensity (Pertl, 2017). However, poorer performance on these tasks was only found among caregivers of people with ADRD (Correa et al., 2016; de Vugt et al., 2006; Oken et al., 2011), and no differences appeared between caregivers of persons with traumatic brain injury (TBI) and non-caregivers (Moretta et al., 2017).

Caregivers of people with ADRD performed more poorly across a variety of speed of processing tests (Correa et al., 2016; Pertl et al., 2017; Vitaliano et al., 2017). Caregivers of people with ADRD, specifically those who were also over the age of 60, took more time to complete parts A (numbers) and B (letters and numbers) on the Trail Making test (Correa et al., 2016; Palma et al., 2011; Vitaliano et al., 2017). However, after controlling for caregivers’ depression symptoms, Correa’s (2016) findings only remained for part B of the task. Even with this change, performance on part B of the task was consistent across samples; caregivers of persons with ADRD and caregivers of persons with TBI caregivers took more time to complete part B (Mallya & Fiocco, 2018; Moretta et al., 2017) than controls. Alternative tests of

processing speed, such as the digit symbol coding subtest of WAIS-III and the color trail test, also yielded findings consistent with those described above. Specifically, caregivers of people with ADRD performed worse than controls across several studies using the WAIS-III measure (Caswell, et al., 2003; de Vugt et al., 2006; Vitaliano et al., 2007; 2009; 2017) and in some studies, continued to perform poorly across time (Vitaliano et al., 2007; 2009; 2017). Similarly, this caregivers of persons with ADRD completed the color trail test more slowly than controls (Pertl et al., 2017), though this finding was not found in a more recent study by O’Sullivan (2018).

Cognitive performance is likely influenced by sample characteristics and differences in study methodology (de Vugt et al., 2006; Lee et al., 2004; Pertl et al., 2015; Vitaliano et al., 2009; 2017), but even when controlling for these factors, findings remain consistent in demonstrating alterations in the cognitive processes of caregivers. Specifically, EFs like processing speed and inhibition appear to be differentially influenced, at least in part, by participation in caregiving activities (Correa et al., 2016; de Vugt et al., 2006; Oken et al., 2011; Pertl et al., 2017). This is particularly concerning as caregivers use these same processes in many aspects of their care activities (i.e., planning, task switching, and behavior management). Work by Dassel (2008) further highlights the role EFs have on caregiver functioning. Specifically, caregivers who experienced greater executive dysfunction also perceived their care recipients to have poorer functional abilities relative to caregivers with higher EF performance (Dassel & Schmitt, 2008).

Connecting Neural Correlates to Cognition Findings

Along with behavioral measures of cognition, neural measures provide insight into the function of underlying mechanisms supporting cognitive processes. Neural correlates are

examined primarily through the use of neuroimaging techniques such as Magnetic Resonance Imaging (MRI), Functional Magnetic Resonance Imaging (fMRI), and electroencephalogram (EEG). These methods primarily target the association between neuronal activation and cerebral flow and volume, commonly referred to as neurovascular coupling (Chen et al., 2020). More generally, neurons recruit oxygen in a relatively constant state when at rest, creating a similar concentration of oxygenated and deoxygenated blood in the area around the neuron. However, when engaging in cognitive activities, recruitment of additional oxygen occurs, causing an initial spike in deoxygenated blood followed by more consistent increases in oxygenated blood (Chen et al., 2020). It is through this blood-oxygen level-dependent response (commonly referred to as BOLD) that neuroimaging technologies indirectly measure cognitive activities and performance.

While there are many investigations of behavioral and physiological correlates of stress in caregivers, far fewer have examined the neural correlates. Smagula (2017) examined cortical structure changes in caregivers and found increased white matter pathologies in caregivers reporting high levels of strain (Smagula et al., 2017). However, these findings were specific to caregivers currently experiencing depression or depressive symptoms (Smagula et al., 2017), which complicates the ability to apply these results to the general caregiver population. In another set of extant studies by Jain (2021; 2022), the effects of a mindfulness-based stress reduction program were examined, specifically targeting brain connectivity in a sample of caregivers. In these studies, Mentalizing Imagery Therapy was utilized, an intervention technique that directs individuals to connect with their inner thoughts, feelings, and emotions and their external behaviors through guided visualization practice. In both studies, they found an increase in PFC connectivity and fewer mood symptoms after undergoing the program (Jain et al., 2021; 2022).

These findings suggest a potential connection between cortical structure and functional alterations in caregivers, but additional research must be conducted to further define this relationship. In the broader stress literature, evidence supporting cortical alterations from chronic stress is more prevalent. For example, Blix (2013) examined the relationship between long-term occupational stress (i.e., long hours, heavy workload) and brain tissue volume. Their research uncovered a relationship between PFC white matter volumes in stressed participants, such that greater volume reductions were observed in participants with higher stress levels (relative to non-stressed controls). Similarly, Ansell (2012) examined the relationship between adversity and stressful life events and changes in cortical structures. Among their findings, gray matter reductions in the medial PFC were reported by participants endorsing high levels of adversity and stressful life events.

Stress-related cortical structure changes have also been observed in younger populations, including children who experienced adverse childhood events (ACEs) (Kaul et al., 2020), stress in early infancy (Monninger et al., 2020), or regular corporal punishment (Tomoda et al., 2009). Though these studies utilize populations that are not caregivers, they strengthen the connection between chronic stress experiences and subsequent cortical change. Thus, given the changes observed in other chronically stressed populations, examining this phenomenon, both behaviorally and neurologically, in caregivers is warranted.

One method of examining stress-related cortical change in caregivers involves using a technology called functional near-infrared spectroscopy (fNIRS). Similar to fMRI and EEG, fNIRS utilizes light to measure changes in the hemodynamic response. However, fNIRS measures these values individually through light emitters and detectors rather than magnetic fields or electrical signals (Joanette et al., 2008). Although fNIRS technology is limited to

measuring superficial cortical layers (Liu et al., 2015), cognitive processes affected by caregiving stress are largely housed within the PFC, an area of the brain that is frequently examined by fNIRS technologies (Naseer et al., 2015).

This methodology has been used in many aging studies (Albinet et al., 2014; Halliday et al., 2018; Lague-Beauvais et al., 2013; Mohammadi et al., 2021; Newman et al., 2020) and more specific examinations of cognition in caregivers (Wang et al., 2022) and persons with PTSD (Tian et al., 2014). fNIRS has also been used to examine EFs in the PFC both cross-sectionally (Halliday et al., 2018; Albinet et al., 2014; Lague-Beauvais et al., 2013) and longitudinally (Mohammadi et al., 2021; Newman et al., 2020) in older adults. Thus, the versatility of this technology in previous aging and cognition studies provides an opportunity for stress responses in caregivers to be examined.

Parallels Between Caregiving and Posttraumatic Stress Outcomes

Caregivers are uniquely situated for exposure to acute and chronic forms of stress. Caregivers experience acute stressors in their everyday caregiving activities but also chronic stress throughout their role as a caregiver. However, the experience of stress and its manifestation may differ due to variations in coping (Lazarus & Folkman, 1984; Wangliu & Chen, 2024; Pearlin et al., 1990), self-efficacy (Leung et al., 2020; Unver et al., 2016), and resilience (Geschke et al., 2024; Palacio et al., 2020). Physiological factors, such as dysregulation of the HPA axis, may also explain these differences. As reviewed previously, memory and EF are two processes primarily impacted by HPA dysregulation (and general stress) in caregivers. A related population of individuals under this unique type of stress are individuals diagnosed with PTSD (Maeng & Milad, 2017). Scientists and other experts in PTSD pathology posit HPA axis dysregulation as one of the primary mechanisms underlying the disorder and its

symptoms (Dunlop & Wong, 2019; Schumacher et al., 2019). Caregivers report many of the same symptoms as individuals diagnosed with PTSD, including psychological (anxiety, depression, changes in mood, engagement in reckless or destructive behavior), physiological (trouble sleeping; muscle tension; pain; alterations in BP and heart rate; fatigue), and cognitive (alterations in memory, attention, planning, and problem-solving) changes (Hayes et al., 2012; McFarlane, 2010).

Given these similarities, it is surprising that further exploration into overlaps between these populations has not been pursued. Specifically, both PTSD and caregiving literature report replaying past events back in one's mind (Michael et al., 2007). This often comes with a more severe designation in PTSD literature due to its profound impact on the lives of those who experience it (Michael et al., 2007). It is important to note that rethinking is not reserved for clinical diagnosis, as only 6% of the US population officially meets the threshold for PTSD (U.S. Department of Veterans Affairs, 2023), and out of this small percentage, only 22.3% experience severe symptoms (Kessler et al., 2005). Thus, although rethinking is likely more salient in PTSD, the number of individuals who experience sub-clinical levels of these symptoms is likely far greater than those receiving clinical diagnosis. However, it is only in PTSD research that the cognitive effects of this symptom are explored.

Across both fields, rethinking is characterized by changes in affect (Hsieh et al., 2021; Moulds et al., 2020) and psychological symptoms (Kennedy et al., 2020; Wen et al., 2022), but cognitive changes are largely reserved to PTSD research. The cognitive implications of re-experiencing stressors implicate both behavioral and neural factors, with research utilizing neuropsychological testing primarily encompassing the behavioral aspect (Mathew et al., 2022; Nilaweera et al., 2020; Verwoerd et al., 2009). Among their findings, an increased risk of

developing cognitive impairment is prevalent among people with PTSD who report rethinking symptomology (Nilaweera et al., 2020). This finding stems from the French ESPRIT study, a longitudinal study of neuropsychiatric disorders in older adults between 1999 and 2001. Their work suggests lifetime trauma with re-experiencing symptoms to be associated with a 46% increased risk of low global cognition compared to individuals diagnosed with PTSD who do not report re-experiencing symptoms (Nilaweera et al., 2020). This risk was particularly associated with women who reported these symptoms (Nilaweera et al., 2020).

Other domains of EF also experience deficits but they are less prevalent in the PTSD literature. For example, dysfunction in visuospatial working memory was associated with re-experiencing symptoms in a sample of thirty veterans diagnosed with PTSD (Mathew et al., 2022). Moreover, working memory deficits and PTSD diagnosis are also strongly associated in several studies (Schweizer & Dangleish, 2011; Saunders et al., 2015). However, in terms of cognitive control one extant study identified poorer capabilities in individuals with PTSD who reported re-experiencing symptoms (Verwoerd et al., 2009).

When examining neural factors, studies observing the connection between rethinking and EF are scarce but generally provide support for this association. For example, an fMRI study conducted by Spielberg (2015) found rethinking symptoms to be associated with impaired neural connections in a sample of over 200 veterans exposed to military trauma. These impairments affected connectivity between the hippocampus and the top-down control structures in the right prefrontal cortex. Further, neural connections between the insula and the prefrontal cortex were also found to be impaired across the entire sample. Clausen (2017) also examined the relationship between PTSD symptom severity (including rethinking) and cortical structure and function. Their findings demonstrated compromised signaling between the medial PFC and the

rostral anterior cingulate cortices, which was further associated with poorer performance behavioral measures of EF.

Beyond symptoms of PTSD, global cognitive dysfunction (Jenkins et al., 1998; Kivling-Boden & Sunbom, 2003; Vasterling et al., 2002; Yehuda et al., 2005) and executive dysfunction (Hart et al., 2008; Jenkins et al., 2000; Koso & Hansen, 2006; Vasterling et al., 1998; Wrocklage et al., 2016) are commonly reported among individuals with PTSD. These findings are not marginal in effect, with several meta-analyses yielding effect sizes between 0.45 (Scott et al., 2015) and .80 (Schuitevoerder et al., 2013). With these more general findings, as well as the specific dysfunctions related to rethinking symptomology, further examination of the cognitive effects of stress recollection in caregivers may aid in understanding the patterns of cognitive dysfunction seen across caregiving literature.

The Current Study

Due to the growing portion of the U.S. population reaching older adulthood in the next decade, a call for more individuals to enter into the paid and unpaid caregiving spheres has been initiated (AARP, 2020; Alzheimer's Association, 2023; America's Health Rankings, 2023; Giovannetti & Wolff, 2010). With this call to action, researchers have turned to examining the impacts of caregiving on both the care provider and the care recipient (Haley et al., 2020; Lai et al., 2024; Moon et al., 2020; Paulson & Lichtenberg, 2011; Schulz et al., 2021). However, fewer studies have examined a specific symptom of stress in caregivers: rethinking. Similar to individuals with PTSD, caregivers often think about previous stressful caregiving experiences. In PTSD, rethinking is associated with negative changes across psychological, physiological, and cognitive domains (Hayes et al., 2012; McFarlane, 2010); these outcomes have also been seen in stressed caregivers (Del-Pino-Casado et al., 2019; Del-Pino-Casado et al., 2021; Fonareva et al.,

2014). The current study aims to examine the consequences of rethinking in caregivers by examining changes in EF performance and its underlying neural correlates. It is hypothesized that caregivers who are asked to recall stressful caregiving experiences will report higher stress levels compared to participants asked to recall a neutral experience. Further, it is hypothesized that caregivers who recall stressful caregiving experiences before undergoing an EF test will perform more poorly on the test and demonstrate higher prefrontal cerebral oxygenation concentrations than caregivers who recalled neutral experiences before completing the same test.

Guiding Framework: Pearlin's Caregiver Stress Process Model

The present study draws on Pearlin's (1990) Caregiver Stress Process Model as a theoretical guide. Pearlin (1990) situates caregiving stress as a culmination of contextual, societal, and interpersonal factors that are differentially experienced by caregivers. This experience is broken up into four domains: 1) background and context, 2) stressors, 3) mediators of stress, and 4) outcomes (Pearlin et al., 1990). Studies examining contextual and demographic factors related to the caregiving experience have been fruitful, with many citing the influence of age (García-Castro et al., 2022; Kim et al., 2007), gender (Penning & Wu, 2016; Sharma et al., 2016), ethnicity (Moon et al., 2020; Pinqart & Sorensen, 2005), education (Creedle et al., 2012; Poloni et al., 2017), and socioeconomic status (Biegel et al., 1994; Pinqart & Sorensen, 2005) on caregiver stress. Findings from these studies align with differential experiences, such that female caregivers typically report greater levels of perceived stress (Pinqart & Sorensen 2003, 2005; Vitaliano et al., 2003), while Black (Fabius et al., 2020), highly educated (Creedle et al., 2012; Poloni et al., 2017) and higher SES (Biegel et al., 1994; Pinqart & Sorensen, 2005) caregivers typically report lower stress. The literature citing the significance of these variables on

perceived stress informed the decision to include survey measures that collect this information and analyze the results within this context.

Pearlin's (1990) model distinguishes between primary stressors, or stressors directly tied to caregiving, secondary role strain, or the impact of caregiving on outside roles a caregiver has (i.e., family member, employee, etc.), and secondary intrapersonal stressors, or effects that caregiving has on the caregiver's perception of self (i.e., competency, self-esteem). These stressors are captured within the current study materials and interview topics, although the study is focused primarily on the impact of momentary stressors, such as recalling a stressful caregiving event, on prefrontal cerebral oxygenation and EF performance. Additionally, though several of the study measures do serve as potential moderators of caregiver outcomes and may influence the perception of stressors (i.e., demographic factors, care activity factors, self-efficacy), they are not specifically defined as such in the primary analyses. Instead, these factors are included as covariates in the study model, presuming their impact on the outcome variables, EF and prefrontal cerebral oxygenation. Last, the outcome variables in this study are similar to those previously identified in Pearlin's (1990) model: physical health and cognitive disturbance. However, the current study seeks to expand these outcomes by examining a specific aspect of cognitive performance – EF – as well as the neural correlates of this process (i.e., prefrontal cerebral oxygenation). In sum, this study utilizes the characteristics of Pearlin's stress model to inform its methodology but does not emphasize the exploration of potential moderating factors in its results (Appendix A).

Chapter 2: Method

Study Overview

This study was conducted in two stages: 1) a pre-session screening call and 2) an in-person session. The pre-session screening consisted of several questions to determine study eligibility as well as a follow-up survey to collect demographic and caregiving activity information. The in-person session consisted of questionnaires and survey measures, a short interview, physiological and neural measurements, and a cognitive task. Before the in-person session, participants were assigned to either an experimental condition, which asked about caregiving stress experiences, or a control condition, which asked about participant hobbies and leisure time activities. Participants were encouraged to schedule their sessions within 2-weeks of completing the screening interview, however one participant was unable to complete their session until several months after their screening call. These topics are discussed in the interview portion of the in-person session. Questionnaires and survey measures consisted of the Bristol Activities of Daily Living Scale (BALDS) (Bucks et al., 1996), the Self-Efficacy Scale (Steffen et al., 2002), the Stress-Arousal Inventory (Mackay et al., 1978), the Cognitive Failures Questionnaire (Broadbent et al., 1982), and the Zarit Burden Scale (Zarit et al., 1980) and Leisure Time Activity Questionnaire (Przepiorka & Blachnio, 2017), which informed the interview topics. Physiological measurements included BP and pulse, and neural measurements consisted of PFC oxygenation measured by an fNIRS device. The cognitive task included in the study was the AX-CPT, which measured participants' EF performance. A visual representation of this two-part session is shown in Figure 2 (Appendix B).

Participants

39 caregivers of older adults were recruited from Virginia ($n = 35$) and Michigan ($n = 4$) through postering, word-of-mouth referrals, and online advertisements. In total, 36 caregivers of

older adults, including 32 from Virginia and 4 from Michigan, met the eligibility criteria and participated in the study. All caregivers included in the final sample were informal caregivers, at least 18 years old, currently provided care to an older adult (aged 65 years +), and reported no history of major cognitive or cardiovascular conditions. Caregivers ranged in age from 23 to 80 years ($M = 57.61$, $SD = 15.82$); most identified as white (58.3%; $n = 21$), non-Hispanic (100%; $n = 36$), married or partnered (75%; $n = 27$) and female (75%; $n = 27$). Participants typically reported being employed (63.9%; $n = 23$), with an average work schedule of 22.2 ($SD = 20.7$) hours per week. Most of the sample reported having received a higher education degree (89%; $n = 32$), a family income of \$150,000 or greater (33.3%; $n = 12$), and being a child (61.1%, $n = 22$) or spouse (25%, $n = 9$) of their care recipient (Appendix C). Caregivers also reported being in good (52.8%; $n = 19$) or excellent health (41.7%; $n = 15$), with few reporting having high blood pressure (30.6%; $n = 11$) (Appendix D).

In terms of caregiver activities, participants most often reported being the primary person providing care to their recipient (61.1%; $n = 22$). Care recipients were mostly female (72.2%;), and between the ages of 64 and 102 years ($M = 82.08$, $SD = 8.96$), with multiple care needs (38.9%) or care needs that were only physiological in nature (27.8%) (Appendix E). Caregivers reported taking care of their current recipient for an average of 54.28 months ($SD = 75.94$), and this care took up an average of 31.86 hours per week ($SD = 49.15$). Many caregivers also reported previously being a caregiver for another older adult in their life (69.4%; $n = 25$) (Appendix F).

Randomization Procedure

Participant randomization to the experimental groups was facilitated by the use of an online randomizer program (Herrick, 2024), which allowed for randomization into the

experimental and control conditions while accounting for specified covariates. This randomization occurred after the completion of the screening call but before participants arrived for their in-person session. The covariates included in the randomizer were participant (age, gender, race, marital status, education level, relationship to care recipient, history of high BP) and care-recipient (age, gender, nature of care needs) variables, and were collected during the screening phone call.

Functional Near-Infrared Spectroscopy (fNIRS) Methodology

fNIRS utilizes light to measure changes in the hemodynamic response. However, fNIRS measures these values individually through emitters and detectors (Joanette et al., 2008). This technology works by measuring the amount of near-infrared light (e.g., light that has a wavelength between 750 and 1,200 nanometers) that is absorbed by chromophores (e.g., cells with some type of pigment and produce color) in the cortical tissue (Pinti et al., 2020). Oxygenated hemoglobin (i.e., oxyhemoglobin) and deoxygenated hemoglobin (i.e., deoxyhemoglobin) are the chromophores that absorb the light in cortical tissue. The amount of light that is emitted and detected after traveling through the cortical tissue is what allows fNIRS to create an oxygenation ratio (i.e., the amount of oxygenated versus deoxygenated blood in an area at a given time) which indicates what area(s) is active at a given time (Pinti et al., 2020).

Aside from the cost and feasibility advantages, fNIRS has some limitations. Most prominent, fNIRS technology is limited to measuring superficial cortical layers, not deep brain structures (Liu et al., 2015). However, EFs are largely housed within the PFC, an area of the brain that is frequently examined by fNIRS technologies (Naseer et al., 2015). In samples of caregivers and individuals with PTSD, fNIRS measured changes in frontal networks during EF tasks. For caregivers, Wang (2022) examined resting and tasked-based performance in caregivers

of people with Parkinson's Disease and observed decreased activation in the fronto-parietal networks during the Verbal Fluency Test. For individuals with PTSD, Yennu (2016) observed activation differences between control (healthy) and experimental (veteran) populations during the Stroop Task. In veterans, activation in the left PFC was absent and this absence was negatively correlated with incongruent RT trials. Similarly, Tian (2014) observed PFC activations in control (healthy) participants during the encoding and retrieval processes of a digit span task but only during the encoding phase in PTSD veterans.

Given the ability of previous studies utilizing fNIRS to examine PFC functioning during EF tasks, the current study utilized an 8-channel fNIRS device (OctaMon, Artinis, The Netherlands) to measure changes in prefrontal oxygenation in caregivers. An 8-channel system was used due to its cost-effective design and its ability to meet measurement criteria for obtaining adequate PFC measurements (Luu and Chau, 2009; Khan et al., 2014; Naseer et al., 2014). The fNIRS device measures changes in blood oxygenation using continuous-wave near-infrared spectroscopy. This device uses near-infrared light absorption with two distinct wavelengths (760 and 850 nm) to detect changes in hemoglobin and consists of eight light-emitting diode (LED) channels and two detectors spaced 35 mm apart. Each participant was fitted with the device using the modified International EEG 10–20 system (Herwig et al., 2003), and their blood oxygenation was recorded at a sampling rate of 10Hz (Wightman et al., 2015). LED channels were subsequently grouped and averaged by hemisphere, such that Group 1 (G1) consisted of channels T1-T4 and Group 2 (G2) channels T5-T8. A third group "Total," which consisted of all electrodes (T1-T8) was also created to assess whole PFC oxygenation (Appendix H).

Physiological Measures

Physiological changes occur when individuals are exposed to stress, and these changes are frequently measured by researchers, especially those studying individuals diagnosed with PTSD (Edmondson et al., 2018; Morris et al., 2016; Paulus et al., 2013; Sadeghi et al., 2022). When an individual experiences stress, a domino of changes occurs in the human body (American Psychological Association, 2018). Specifically, the brain sends signals calling for the release of stress hormones, which call on cardiovascular, endocrine, and other specific bodily systems to alter their behaviors. For the heart, this includes pumping at a faster and stronger rate (i.e., increasing optical heart rate) and expanding blood vessels to carry more blood to and from the heart (i.e., increasing blood pressure) (American Psychological Association, 2018).

The hemoglobin measurements obtained from fNIRS are subject to artifacts from these responses (Chen et al., 2020), and although these artifacts can be filtered out through analytic methodologies, stress researchers frequently include independent measurements of BP and pulse to better assess their influence on study results. As such, BP and pulse were measured using an automatic BP cuff and a Polar OH1+ Sensor (Polar Electro, Finland). Placement and administration for BP measurements followed guidelines set forth by the American College of Cardiology (Whelton et al., 2017). Following recommendations from Polar, participants were fitted with the sensor on their forearm. In terms of psychometrics, the OH1+ sensor has been verified to measure optical heart rate (pulse) during exercise and yields high consistency (interclass correlation ranging between .98-.99) (Hettiarachchi et al., 2019) and reliability (ranging between 92-99%) (Hermand et al., 2019) across measures.

Behavioral Measures

Behavioral measures utilized in this study assess the influence of demographic, caregiving, and health factors on EF performance and hemodynamic response. Previous studies highlight the importance of these factors in caregiving research (Brown & Brown, 2014; García-Castro et al., 2022; Robison et al., 2009; Roth et al., 2015; Schulz & Sherwood, 2008). Each measure (described below) was chosen based on its ability to measure particular variables related to these factors and demonstrated adequate psychometric properties.

Bristol Activities of Daily Living Scale

The Bristol Activities of Daily Living Scale (BADLS) (Bucks et al., 1996) measured the functional capabilities of care recipients from the perspective of the caregiver. The BADLS is a 20-item scale that covers daily living activities like eating and brushing one's teeth. Each question is measured using a 4-point scale that assesses the level of dependence (0 = *totally independent*, 3 = *totally dependent*), with a fifth "non-applicable" option. Scoring consists of summing all responses to acquire a total score, which can then be conceptualized as the level of dependency of the care recipient (0 = *totally independent*, 60 = *totally dependent*). The validity of the scale was established by correlating its scale with the Mini-Mental State Examination (MMSE), a previously established measure of functionality. Validity between these two measures was 0.67 (Bucks et al., 1996).

While popular for use in populations of persons with ADRD, this measure has been used in clinical trials to assess primary or secondary outcomes in pharmaceutical and psychosocial interventions. These include studies such as Kehoe's (2021) clinical trial examining the use of Losartan, a blood pressure drug, for reducing brain atrophy in ADRD, Howard's (2020) trial on Minocycline, a drug used to treat infections, for treating in mild ADRD, and Bourne's (2021)

dyadic arts intervention program for patients with ADRD and their caregivers. It has also been used in studies examining physiological conditions such as peripheral vascular disease (Safer et al., 2023) and in psychiatric populations like those diagnosed with major depressive disorder (Knight et al., 2021). Further, BADLS has also been used to measure caregiver perceptions of recipient capabilities across a variety of outcomes (Burch & Burch, 2021; Lewis & Riley, 2021; Ryan & O’Brady, 2023). Specifically, BADLS scores have been used as model predictors of caregiver outcomes (Alexopoulos et al., 2023) and to assess the effect of intervention programs like Cognitive Stimulation Therapy on caregivers (Orgeta et al., 2015).

The present study examined caregiver stress across a larger population of care recipients, including persons diagnosed with ADRD, physiological, or psychological conditions. With its use in studies examining these broader populations, this measure was included as a covariate to assess differences in caregiver stress levels based on the functional capabilities of their care recipient. Additionally, a critical feature of BADLS is that it is a measure designed to be administered and completed by the caregiver (Bucks et al., 1996). The current study focused on perceived caregiver stress, which primarily focused on perceptions of the caregiver about their care activities. Thus, including a measure of recipient functionality from the perspective of the caregiver allowed for subjective perceptions of the caregiver to be measured.

The Revised Scale for Caregiving Self-Efficacy

Across caregiving literature, self-efficacy is identified as an influential factor in caregiver outcomes, especially stress-related outcomes (Khan et al., 2021; Sato et al., 2021). For example, several studies have identified the positive influence of caregiver self-efficacy on perceived quality of life (Cheng et al., 2023; Kuo et al., 2014; Liu et al., 2023) and its ability to lessen feelings of burden (Cheng et al., 2013; Phongtankuel et al., 2023). Distress and self-rated health

of caregivers were also found to be mediated by self-efficacy in several studies including those by Wawrziczny (2021) and Nogales-Gonzalez (2014). However, research on the influence of self-efficacy on cognitive performance in caregivers is slim. In one extant study by Pertl (2017), the role of cognitive reserve and self-efficacy as moderators of caregiver cognitive performance was examined. While cognitive performance was found to moderate this relationship, self-efficacy was not significant. However, several studies have yielded positive associations between self-efficacy and cognitive performance across the lifespan, including in school-aged children (Horcajo et al., 2022; Wang et al., 2023), young adults (John et al., 2023) and adults over the age of 65 (Lucas et al., 2016; Rimmele et al., 2022).

Given these findings, self-efficacy was included as a covariate to account for its role in caregiver stress and EF. To measure this construct, the Revised Scale for Caregiving Self-Efficacy (Steffen et al., 2002) was used. The scale includes 15 items assessing a person's belief in their ability to successfully engage in certain kinds of behavior. Three subscales are included that focus on behaviors relating to obtaining respite, responding to disruptive care recipient behaviors, and controlling negative or upsetting thoughts about caregiving. Each item asked participants to rate their confidence in their ability to carry out certain behaviors on a scale of 0 to 100 ("How confident are you that you... Can ask a friend/family member to stay with [care recipient] for a day when you need to see a doctor for yourself?"). Scoring consists of summing responses and dividing by the number of items answered per subscale. Although each subscale consists of 5 items, items marked "non-applicable" were excluded from this average. Thus, participants have an average confidence score (0-100) for each subscale. The scale also yields strong psychometrics like test-retest reliability and internal consistency both in U.S. and cross-national samples (Steffen et al., 2019). Reliability metrics for self-report administration of the

scale range between $\alpha = .90 - .95$, with unidimensional (full-scale) metrics $\alpha = .90$ (for a review, see Steffen et al., 2019).

Stress and Arousal Inventory

Stress and arousal scores were included as both a predictor and an outcome variable. Perceived stress is identified as a predictor of caregiving burden (Ozkan Tuncay et al., 2019; Pinyopornpanish et al., 2021), and is related to other outcomes like cardiovascular health and well-being (Capistrant et al., 2012a; Capistrant et al., 2012b; Jian et al., 2022) and psychological symptoms like depression and anxiety (Moghaddam et al., 2023). When examining caregivers' cognitive function, stress is also related to cognitive performance outcomes (Falzarano & Siedlecki, 2021; Wu-Chung et al., 2022), especially among caregivers of older adults (Caswell et al., 2003; Lee et al., 2004). In terms of arousal, evidence of a positive association between physiological arousal and perceived stress in caregivers has been found (Chattilion et al., 2012; Roepke et al., 2008). For example, in a study by Roepke (2008), sympathetic arousal in stressed caregivers was mediated by perceived self-mastery, such that higher mastery was associated with lower arousal. However, examining caregiver arousal and its relationship to cognitive performance independently of stress is difficult due to its close association with stress (Chattilion et al., 2012).

Thus, to independently measure both stress and arousal, the Stress and Arousal Inventory (Mackay et al., 1978) was used in the present study. The inventory consists of 34 adjectives that make up "stress" ($n = 19$) and "arousal" ($n = 15$) subscales. "Stress" is conceptualized as a response to the favorability of the environment, whereas "arousal" is the level of activation of a person (Mackay et al., 1978). In the measure, some adjectives that code for stress are "tense," and "bothered" whereas arousal adjectives are "alert" or "lively." For each adjective, participants

were asked to indicate the degree to which they were currently experiencing it using a 4-point scale (*Definitely Feel*, *Slightly Feel*, *Cannot Decide* or *Do Not Understand*, *Definitely Do Not Feel*). Positive adjectives were given a score of 1 if a participant answered, “*Definitely Feel*” or “*Slightly Feel*” and a score of 0 if any other answer was given. Negative adjectives are given a score of 1 if participants answered “*Cannot Decide* or *Do Not Understand*” or “*Definitely Do Not Feel*” and a score of 0 for all other answers. Higher scores indicated lower levels of stress and arousal.

The psychometric properties of the Stress-Arousal Inventory, such as its validation of bipolar dimensions, have been validated by independent analysis (McCormick et al., 1985) and have provided the basis for additional stress and arousal measures (Fischer & Donatelli, 1987). Given these criteria, Mackay’s (1978) measure was chosen for use in this study.

The Cognitive Failures Questionnaire

Experiencing cognitive slips or errors is relatively normal in everyday life. Common experiences include walking into a room and forgetting what you need or forgetting where you left your keys. However, the magnitude and frequency of these failures provide insight into cognitive functioning. For example, literature examining how cognitive failure scores reflect in performance outcomes indicates an inverse relationship (Broadbent et al., 1986; Tipper and Baylis, 1987). More specifically, high scores on the Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982) are indicative of specific deficits in attention and cognitive control (Broadbent et al., 1986; Tipper and Baylis, 1987).

In the present study, EF domains of processing speed and attention were assessed. To control for the effects of cognitive failures in participant performance on the AX-CPT, the CFQ (Broadbent et al., 1982) was utilized. The CFQ consists of 25 questions that assess the frequency

and severity of normal cognitive dysfunctions in the past 6 months (i.e., “Do you read something and find you haven’t been thinking about it and must read it again?”). Three subscales (forgetfulness, distractibility, and false triggering) are included in the measure and consist of attention, memory, perception, and motor function components of cognition (Rast et al., 2009). Participants rated each question on a 5-point scale (0 = *Never*, 4 = *Very Often*) based on the frequency of each cognitive failure, and a score was subsequently created for each subscale. Higher scores indicated greater disfunction in each dimension. A total score may also be created for the measure, which can be used to assess the degree of propensity for cognitive failure (Bridger et al., 2013), with lower scores indicating greater EF performance (Banich, 2009).

The CFQ (Broadbent et al., 1982) has been widely used and validated among researchers. Bridger (2013) examined the measure’s test-retest reliability and yielded a score of .71 over a 2-year period in addition to a consistent item structure rating of 0.5. These ratings are considerably higher than other measures, like the General Health Questionnaire (GHQ-12) (Goldberg & Williams, 1988), as their reliability was 0.32 over the same period (Bridger, 2013). Given these properties, the CFQ was determined to be an adequate measure to assess recent cognitive disruptions in the present sample of caregivers.

Zarit Burden Interview

In the present study, caregiver burden is an independent variable of interest and the subject of the experimental condition. This specific form of burden is uniquely experienced by caregivers and often occurs when care activities exceed available resources (Liu et al., 2020). The effects of this burden are widespread, including psychological (Halpern et al., 2017), physical (Thana et al., 2021), and cognitive consequences for the caregiver (Wennburg et al., 2023). For example, caregiving burden has been associated with increased anxiety and

depression symptoms (Halpern et al., 2017), changes in cardiovascular and metabolic response (Thana et al., 2021), and poorer global, memory, and EF performance (Wennburg et al., 2023).

A frequently used measure of caregiving burden is the Zarit Burden Interview (ZBI) (Zarit et al., 1980). The ZBI is a 22-item measure utilized to assess caregiver burden. During the measure, Caregivers are asked to rate their endorsement of each item using a 0 (Never) to 4 (Nearly Always) scale (“Are you afraid of what the future holds for your relative?”). Scoring for the measure varies depending on the source, but a generally accepted scoring procedure is creating a total score for the measure. Score interpretations fall into four ranges of burden: no to mild burden (0-20), mild to moderate burden (21-40), moderate to severe burden (41-60), and severe burden (≥ 61).

The ZBI has demonstrated good psychometric properties across time. Internal consistency, a measure of reliability, ranges between 0.70 and 0.93 (Lu et al., 2009; Özlü et al., 2009; Bianchi et al., 2016). Test-retest and inter-observer evaluation yield positive results as well, with interclass correlations of 0.88 (Taub et al., 2004) and 0.78 (Rajabi-Mashhadi et al., 2015). With these parameters and frequent use in the caregiving literature, the present study included the ZBI as the measure of burden for the experimental condition and was used to facilitate recall of stressful caregiving experiences during their interview. This measure was not given to participants assigned to the control condition.

Leisure Time Activity Questionnaire

The current study also implemented a control condition to examine differences in cognitive performance and PFC oxygenation between caregivers who recall stressful caregiving experiences and those who do not. Literature suggests that participating in leisure activities may moderate the relationship between caregiving demands/burden and the psychological and

physiological changes associated with caregiving like depression symptomology (Mausbach et al., 2011) and bodily arousal (Chattillion et al., 2012). To examine the potential differences between experimental groups on the outcome variables of interest (EF, PFC oxygenation), the Leisure Time Activity Questionnaire (LTAQ) was utilized (Przepiorka & Blachnio, 2017). The LTAQ consists of 16 statements about various leisure activities to which respondents must rate their agreement using a 5-point scale (0 = *Totally Disagree*, 4 = *Totally Agree*). Included in this scale are four subscales measuring specific types of leisure: socializing with friends, using the internet, leisure time management, and winding down. Participants assigned to the control condition in the present study were asked to complete this questionnaire, and their answers were discussed in a follow-up interview. Participants assigned to the experimental condition did not receive this questionnaire. Psychometrics for the LTAQ were established by the creators of the scale, including reliability ratings between .70 to .87 across samples.

The Modified AX-Continuous Performance Test

To measure EF, the Continuous Performance Test (CPT), specifically the AX-CPT, (Cohen et al., 1999) was used. The CPT test measures cognitive control, specifically in the context of attention, goal maintenance, and inhibition. This measure has been widely used in studies examining age-related (Mani et al., 2005; Polizzotto et al., 2018) and PTSD-related changes in EF (Lee & Jung, 2022; Shucard et al., 2008). For example, age-related reductions in attention and inhibition were observed in older adults as well as response slowing in populations of individuals diagnosed with PTSD or who exhibited PTSD-like symptoms (Lee & Jung, 2022).

The specific version of the CPT used in this study uses the letters “A” and “X” as the target letter pairing (Appendix I). In this task, a stream of letters are presented one at a time on a computer screen. Participants must respond to the target letter using one response key and non-

target letters with another. The target letter is an “X” but only when presented after the letter “A.” The letter pairings serve a specific purpose in the task. Trials that begin with the presentation of the letter “A” provide a context clue. Using this context clue, as well as the increased frequency of target “AX” trials (relative to non-target, AY, BY, BX) an environment susceptible to response bias is created. In other words, the number of target trials is greater than non-response trials, which makes it more likely that participants will respond as if the trial is a target when it may not be so. When participants respond to a non-target trial with a target response, this is referred to as “interference.” When the “B” letter is introduced in a trial, this is included to overcome the response bias when “X” is presented in non-target trials (BX). To measure baseline performance ability, the “BY” trial is included (Truong et al., 2022).

Given the time constraints associated with assuming a caregiving role, a shortened version of the AX-CPT task was implemented for the study, which included 4 trial blocks instead of 8. To become familiar with the task instructions, a 30-trial practice session was implemented before the scored testing period. If participants seemed to struggle with understanding the rules, they were given an extra training period.

To assess participant performance, block averages were used for analyses, which calculated performance across sets of trials within the task and the entire task. For analyses, average RT and accuracy were calculated for each trial type. Total RT and accuracy calculations were also examined. To calculate the average RT for each letter pairing, response times for each letter were individually summed and then divided by 2. Total RT was subsequently calculated by summing the average RT for each letter pairing (AX, AY, BX, BY) and dividing this number by 4. Total accuracy was calculated using similar methods – first, the number of correct responses was summed for each letter pairing and then divided by the number of trials for that pairing (i.e.,

AX = 336, AY, BX, and BY = 48 each). Percentage correct (accuracy) was then calculated by multiplying each pairing's accuracy score by 100. Subsequently, total accuracy was calculated by summing each letter pairing's accuracy score and dividing this number by 4.

Using accuracy and RT as separate measurements of performance provides insight into mechanisms of proactive and reactive control, two strategies embedded in cognitive control processes (Braver, 2012). When exhibiting proactive control, relevant information is actively stored and sustained until the action is complete, which leads to higher focus or attention. This can lead to bias in cognitive processing, such as increased attention on cues (A's) rather than targets (X's) and participants will be more likely to respond to "AY" trials as though they contain the target ("X"). For RT and accuracy, this means that responses to stimuli may be quicker and more accurate in "AX" and "BX" trials, but slower and less accurate in "AY" trials. It is in the "AY" trials that inhibition is specifically measured in the task.

In reactive control, this is the opposite. Instead of anticipating cues, participants wait for the cue to be presented and then respond. In this sense, slower response times and greater errors in "AX" and "BX" trials are present, but also faster response times and fewer errors in "AY" trials. As a result of participants having to reactivate the cue response (instead of holding it in their mind actively), more errors are likely due to having to reactivate that cue every "AX" and "BX" trial.

Both proactive and reactive control mechanisms are housed within the PFC but differentially activate. Whereas proactive control is associated with increased activation in the lateral PFC (likely due to the maintenance of contextual information in this type of control), reactive control is associated with transient increased activation across the larger frontoparietal network (Braver et al., 2009; Paxton et al., 2008). The current study measures both EF

performance and PCF activation using fNIRS technology, thus allowing for further insight into whether and how these patterns emerge in caregivers who recall stressful experiences.

Experimental Procedure

Participants were recruited in Michigan and Virginia by online advertisements, posterings, and word-of-mouth referrals. Upon contact, participants completed a screening questionnaire to determine their eligibility for the study and gather basic demographic, health, and caregiving information. Inclusion criteria included participants who: 1) were over the age of 18, 2) were currently providing care to an adult aged 65 years and older, 3) did not have a history of any major cardiovascular or cognitive conditions, and 4) were willing to participate in a follow-up in-person session. Participants were screened over the phone, and if determined to be eligible for the study, were asked questions about their demographics, health, and caregiving activities. Upon completion of the screening call, the researcher and participant coordinated a date, time, and location for the in-person session. If participants preferred to come to the CAATS Lab space, the researcher followed their screening call with an email containing appointment information (date/time) and the location of the lab. If participants preferred a researcher to come to their home for the session, the researcher gathered their addresses and followed the screening call with an email containing appointment information (date/time) and a confirmation of the session location.

At the scheduled appointment time, the researcher met the participant at the agreed-upon location. When meeting at the lab, the researcher met the participants in the lobby and escorted them to the office where the session would be occurring. This office consisted of two rooms, one room containing three desks with computers, and the other, a room containing a desk, filing cabinets, and a table for participants to sit at. When completing the session at a participant's

home, the researcher and participant chose a quiet room within the home to conduct their appointment. The spaces chosen were generally either a dining room, living room, or kitchen with a breakfast bar.

The session began with the consent procedure, which involved the participant reading through an IRB-approved document (provided at the in-person session) and providing a signature to move forward with the session. Before signing, participants were asked about any questions they had and given answers by the researcher. To begin the session, the researcher gave each participant four questionnaires, one at a time, and provided verbal instructions for each. These questionnaires included the BALDS, Self-Efficacy Scale, Stress-Arousal Inventory, and the Cognitive Failures Questionnaire and generally took participants 10 to 15 minutes to complete. Participants were allowed to ask questions during these measures, and when permitted, the researcher responded accordingly.

After completing the questionnaires, the researcher introduced the participant to the pulse, BP, and fNIRS technologies and allowed them to ask any questions. Following these questions, the researcher fitted participants with the pulse sensor and asked participants to relax for 30 seconds while the measurement was being performed. The average pulse of the participant was recorded on a check sheet. Next, the researcher fitted participants with a BP monitor. ACC guidelines for placement and administration were followed for placement and measurement. After the machine completed its reading, the researcher recorded the systolic and diastolic BP on the same check sheet. Participants were allowed to see their readings after completion of the measurement. Following this, the fNIRS device was fitted on the participant, and the researcher instructed the participant to relax for 30 seconds while a baseline measurement was recorded.

Following the completion of the fNIRS measurement, the participant was given a survey asking about their stressful caregiving experiences or hobbies. After completing this survey, the researcher reviewed their answers, noting the questions or statements that received high agreement or frequency scores. The researcher then conducted the interview session with participants. During this session, the researcher prompted participants to discuss answers that they rated highly. Follow-up questions were asked by the researcher to further understand their answers, but these were unstructured. The interview lasted roughly 10 minutes in length. During this interview session, active pulse and fNIRS measurements were taken.

The researcher then instructed participants on the rules regarding the AX-CPT task. This instruction included a verbal description of the rules as well as visual examples of the task. Upon completion of this instruction, participants were allowed to complete a round of practice trials. This practice was completed either on a desktop computer (in-lab session) or a laptop (at-home session). If participants did not seem to grasp the task, instructions for the task were given again, and participants were allowed to repeat the practice trials. Although participants were not given an explicit limit on the number of times they could redo the practice trials, only a single additional practice session was ever taken by participants. Once the participant grasped the rule set, the researcher prepared the scored AX-CPT task. In sessions conducted at the lab space, the researcher seated participants in the computer room and waited in the main office space while they completed the AX-CPT. During this time, active pulse and fNIRS measurements were taken. For at-home sessions, participants were moved to a seat further away from the researcher, and the same physiological measurements were taken while they completed the task. After completing the AX-CPT, participants were reseated in the main lab space (or when in-home, returned to their original seat by the researcher) and were asked to complete the Stress-Arousal

Inventory for a second time. Following the completion of this measure, participants were debriefed and compensated. An overview of the study process is included in Appendix B.

Data Processing of fNIRS Signal

Neural PFC data was collected and analyzed using Oxysoft (Artinis Medical Systems, Netherlands). Pre-processing of the data included visual inspection and bandpass filtering using .1 (low) and .4 (high) cutoff values (Naseer & Hong, 2015). These cutoff values remove extraneous artifacts such as motion and physiological noise that fall outside of these ranges (Naseer & Hong, 2015). For participants between the ages of 18 and 50, the differential path length factor (DPF) was calculated using the formula: $DPF = 4.99 + 0.067 \times (\text{Age}^{0.814})$. For participants above 50 years of age, the DPF was set at 6 for each measurement, which is the recommended DPF value for this age group (Duncan et al., 1996). Relative concentration changes were calculated from optical density signals using the modified Beer-Lambert Law (Obrig & Villringer, 2003), which is applied automatically within the Artinis software (Oxysoft Artinis Medical, Netherlands). This formula provides the best estimate for light path length by removing the effect of tissue scattering (Baker et al., 2014). These density signals were then averaged for each of the 8 channels (using a function built into Oxysoft), and subsequent G1, G2, and Total average optical density signals were created. The resulting oxygenated hemoglobin values were utilized in the analyses, including the calculated changes of oxygenation between measurements (i.e., baseline & AX-CPT) and within the left (optodes 1-4), right (optodes 5-8), and total PFC.

Chapter 3: Results

Group Differences

Although randomization helps to control for group differences, subsequent differences at baseline were examined using a series of independent samples t-tests (for continuous outcome variables), and chi-square tests (for categorical outcome variables). In cases where inadequate cell counts were present for Chi-square tests, Fisher's exact test was used to report results.

Few differences were present between caregivers assigned to the experimental conditions. Age ($t(34) = -0.839, p = 0.407$), gender (Fisher's exact test ($p = 1.00$)), race ($X^2 (3, N = 36) = 1.762, p = 0.623$), education ($X^2 (3, N = 36) = 9.00, p = 0.087$), marital status (Fisher's exact test ($p = 0.443$)), employment status ($X^2 (1, N = 36) = 1.084, p = 0.298$), and income ($t(34) = 0.122, p = 0.903$) did not vary significantly between groups. Ethnicity was not tested due to all participants ($N = 36$) identifying as non-Hispanic. Health characteristics such as self-rated health ($X^2 (2, N = 36) = 0.119, p = 0.942$), HBP history ($X^2 (1, N = 36) = 0.131, p = 0.717$), HBP medication use ($X^2 (1, N = 36) = 0.131, p = 0.717$), pulse ($t(31) = -0.057, p = 0.955$), systolic BP ($t(34) = 0.456, p = 0.651$), and diastolic BP ($t(34) = 1.572, p = 0.125$) also yielded no significant differences.

In terms of caregiving activities, experimental groups did not differ significantly based on average weekly care hours ($t(33) = 0.411, p = 0.684$), current caregiving duration ($t(34) = 0.316, p = 0.754$), primary caregiver status ($X^2 (1, N = 36) = 0.468, p = 0.494$), previous or other caregiving activities ($X^2 (1, N = 36) = 0.131, p = 0.717$), or duration of previous or other caregiving ($t(32) = -1.036, p = 0.308$). Additionally, care recipient characteristics such as recipient age ($t(34) = -0.571, p = 0.572$), gender (Fisher's exact test = 1.00), type of care needs ($X^2 (5, N = 36) = 3.733, p = 0.588$), relationship to caregiver ($X^2 (4, N = 36) = 2.626, p = 0.622$),

or score on the BADL assessment ($t(34) = -0.788, p = 0.436$) did not significantly differ between groups.

Baseline measures of self-efficacy, cognitive failures, stress, and arousal yielded significant differences between groups. Specifically, stress ($t(34) = -2.324, p = .026$), but not arousal ($t(34) = -1.527, p = 0.136$) was higher among caregivers assigned to the experimental condition ($M = 10.83, SD = 3.29$) than those assigned to the control condition ($M = 8.17, SD = 3.59$). No other significant relationships were found between scale scores and interview conditions. More specifically, caregivers did not vary between groups based on self-efficacy subscales; obtaining respite ($t(34) = -0.171, p = 0.866$), controlling thoughts ($t(34) = 0.946, p = 0.351$), or responding ($t(34) = 0.062, p = 0.951$). Similarly, caregivers did not vary based on their overall performance on the Cognitive Failures Questionnaire ($t(33) = 0.268, p = 0.790$) nor in their forgetfulness ($t(33) = 0.753, p = 0.457$), distractibility ($t(33) = 0.291, p = 0.773$), or false triggering ($t(33) = 0.518, p = 0.608$) subscale scores (Appendix G).

Covariates

Determining which variables to include as covariates in the analyses was facilitated by reviewing the literature and through examination of each variable and their correlations with the outcomes of interest. Specifically, demographic factors such as age (García-Castro et al., 2022; Kim et al., 2007), race (AARP, 2020; Ejem et al., 2018; Tran et al., 2023; Whitney et al, 2023), gender (Akpinar et al, 2011; Bookman & Kimbrel, 2011; Sharma et al., 2016), marital status (Liu et al., 2023; Wu-Chung et al., 2022), SES (Brown & Brown, 2014; Robison et al., 2009; Roth et al., 2015; Schulz & Sherwood, 2008) and education (Creedle et al., 2012; Poloni et al., 2017) demonstrated relationships with caregiver outcomes in the literature and were included subsequent analyses as covariates.

All baseline variables were correlated with the study outcomes variables to examine any significant relationships. Demographic variables such as age, gender, and race were associated with baseline stress ratings on the Stress Arousal Inventory, as well as RT and oxygenation measurements during the AX-CPT. The strongest relationship found between baseline variables and the outcomes of interest was the impact of caregiving duration. Specifically, duration of current caregiving activities was strongly related to RT and accuracy performance on the AX-CPT. The relationship between previous caregiving activities and outcome measures was weaker, but many caregiving studies identify the importance of cumulative experiences on cognitive, physical, and mental outcomes (Blix et al., 2013; Caputo et al., 2016; Rabinowitz et al., 2007) as well as stress research (Chen et al., 2022; D'Amico et al., 2023; Haight et al., 2023; Mann et al., 2021). As such, lifetime caregiving duration, a variable combining current and previous caregiving activity durations, was utilized as a covariate in the model. In sum, the only covariates included in subsequent models were those that were significant in both the literature as well as those supported by the current study's correlational analyses: age, gender, race, marital status, income, education, and lifetime duration of caregiving (see Appendices J-N).

A priori Research Questions

Research Question 1: Does recalling caregiving experiences increase participants' self-reported stress? Univariate ANCOVAs were conducted to answer this question. Stress scores from the second administration of the Stress-Arousal Inventory were included as the dependent variable and interview condition was included as the fixed factor. Covariates included those described previously. It was hypothesized that participant stress levels would significantly differ between the two interview groups, such that caregivers who were interviewed about stressful caregiving experiences would report higher stress scores following the interview. The

first univariate ANCOVA examined the unadjusted model, which did not include covariates whereas the second model included covariates in its analysis. Differences between these models were not present as post-interview stress scores did not differ by interview type in either the unadjusted ($F(1, 34) = 0.004, p = 0.948$) or adjusted ($F(1, 27) = 0.033, p = 0.857$) models.

Follow-up repeated-measures ANCOVAs were conducted to examine whether stress scores changed across time for participants. Examining differences between interview conditions, participant stress scores did not differ across measurement occasions on either the unadjusted model ($F(1, 34) = 0.793, p = 0.380$) or the adjusted model ($F(1, 28) = 0.871, p = 0.359$). When examining changes in stress scores within participants, stress scores did not vary across time (unadjusted: $F(1, 34) = 2.188, p = 0.148$; adjusted: $F(1, 28) = 1.128, p = 0.297$) nor when examining the interaction between these scores and interview condition (unadjusted: $F(1, 34) = 1.116, p = 0.298$; adjusted: $F(1, 28) = 0.285, p = 0.598$).

Additional post hoc ANCOVAs were conducted to examine changes in participant arousal scores across interview conditions. Participant post-interview arousal scores did not differ by interview type on either the unadjusted ($F(1, 34) = 0.63, p = 0.803$) or adjusted ($F(1,27) = 0.363, p = 0.552$) models. To determine whether arousal scores changed across measurement occasions (i.e., pre-interview and post-interview), a repeated measures ANCOVA was conducted using the same covariates (age, gender, race, marital status, income, education, lifetime duration of caregiving) and fixed factor (interview condition). Within-subject arousal scores were significant in the unadjusted model ($F(1, 34) = 9.982, p = 0.003, \eta^2 = 0.227$), but not in the adjusted model ($F(1, 28) = 0.473, p = 0.497$). However, there was an effect of interview condition on self-reported arousal scores within-subjects in both the unadjusted ($F(1, 34) = 5.562, p = 0.024, \text{partial } \eta^2 = 0.141$) and adjusted ($F(1, 28) = 8.785, p = 0.006, \text{partial } \eta^2 =$

0.239) models. Between-subject arousal scores were not significant in either model (unadjusted: $F(1, 34) = 1.627, p = 0.211$; adjusted: $F(1, 28) = 1.420, p = 0.243$).

Research Question 2: Do caregivers perform worse on an executive function task after completing an interview about stressful caregiving experiences? Multivariate ANCOVAs were used to answer this research question. AX-CPT total RT and total accuracy scores were included as dependent variables and interview condition was included as a fixed factor. For adjusted models, age, gender, race, marital status, income, education, and lifetime duration of caregiving were included as covariates. It was hypothesized that participants assigned to the caregiving stress interview would perform more poorly on the AX-CPT task relative to participants assigned to the hobby interview.

Interview condition was not significantly associated with average RT (unadjusted: $F(1, 34) = 1.391, p = 0.246$; adjusted: $F(1, 27) = 1.356, p = 0.254$) or accuracy (unadjusted: $F(1, 34) = 2.268, p = 0.141$; adjusted: $F(1,27) = 1.826, p = 0.188$) on the AX-CPT task (Appendix O). Mean reaction time was higher for participants assigned to the caregiving stress interview (unadjusted: $M = 394.47, SD = 20.89$; adjusted: $M = 391.74, SE = 17.47$) relative to those assigned to the hobby interview ($M = 359.63, SE = 17.47$). Moreover, overall accuracy on the AX-CPT was higher for participants in the hobby interview (unadjusted: $M = 95.9, SE = 3.8$; adjusted: $M = 94.86, SE = 3.38$) relative to those in the caregiving stress interview (unadjusted: $M = 87.8, SE = 3.38$; adjusted: $M = 88.26, SE = 3.38$).

Lifetime caregiving duration was significantly associated with RT performance on the AX-CPT ($F(1, 27) = 7.101, p = 0.013, \eta^2 = 0.208$) (Appendix P), but not accuracy ($F(1, 27) = 0.118, p = 0.734$). To further investigate, specific trial types within the AX-CPT task (AX, AY, BX, BY) were analyzed using a series of univariate ANCOVAs.

Reaction Time. Lifetime duration of caregiving was significantly associated with performance on AX ($F(1, 26) = 9.895, p = .004, \eta^2 = 0.276$), AY ($F(1, 26) = 6.165, p = 0.02, \eta^2 = 0.192$), and BY ($F(1, 26) = 10.641, p = 0.003, \eta^2 = .290$), but not BX ($F(1, 26) = 1.027, p = 0.320, \eta^2 = 0.038$) trials.

Accuracy. Lifetime duration of caregiving was significantly associated with accuracy on BX ($F(1, 27) = 5.490, p = 0.027, \eta^2 = 0.169$) trails, but not AX ($F(1, 27) = 0.130, p = 0.721, \eta^2 = 0.005$), AY ($F(1, 27) = 1.721, p = 0.201, \eta^2 = 0.060$), or BY ($F(1, 27) = 0.002, p = 0.968, \eta^2 = 0.000$) trials.

Research Question 3: Do caregivers who recall stressful caregiving experiences demonstrate reduced prefrontal cerebral perfusion while completing an EF task? To answer this research question, three repeated measures ANCOVAs were conducted using baseline oxygenation (total, left, right) and AX-CPT oxygenation (total, left, right) measurements as the within-subjects factor, interview condition as the fixed factor, and age, gender, race, marital status, income, education, handedness, and lifetime duration of caregiving as covariates. BP (systolic and diastolic) and pulse variables were not included in these analyses based on non-significant correlations with outcome variables. It was hypothesized that participants assigned to the caregiving stress interview would experience significantly greater decreases in PFC oxygenation relative to participants assigned to the hobby interview.

Total Oxygenation. Examining the effect of interview on total oxygenation during the AX-CPT yielded non-significant results, such that interview condition was not related to total oxygenation on the AX-CPT (unadjusted: $F(1, 33) = 2.448, p = 0.127$; adjusted: $F(1, 25) = 1.976, p = 0.172$). However, activation was significant within-subjects (unadjusted: $F(1, 33) = 127.660, p < .001$; adjusted: $F(1, 25) = 4.767, p = 0.039$, partial $\eta^2 = 0.160$), and mean

activation increased for all participants across measurement occasions (adjusted: Baseline: $M = 1.02$, $SD = 5.27$, AX-CPT: $M = -27.75$, $SD = 13.60$; unadjusted: Baseline: $M = 1.04$, $SD = 0.91$, AX-CPT: $M = -27.67$, $SD = 2.14$) (Appendix Q).

Hemispheric Oxygenation. Results for the effect of interview on hemispheric oxygenation during the AX-CPT were mixed. For G1 (T1-T4) no significant relationships were present between interview type and AX-CPT oxygenation using either unadjusted ($F(1, 33) = 1.535$, $p = 0.224$) or adjusted ($F(1, 25) = 2.134$, $p = 0.157$) models, but oxygenation between measurement occasions was significant in both unadjusted ($F(1, 33) = 116.425$, $p < .001$, partial $\eta^2 = 0.779$) and adjusted ($F(1, 25) = 4.032$, $p = 0.056$, partial $\eta^2 = 0.139$) models. Participant activation in G1 increased across baseline (unadjusted: $M = 0.99$, $SD = 5.50$; adjusted: $M = 1.01$, $SE = 0.95$) and AX-CPT (unadjusted: $M = -26.81$, $SD = 13.52$; adjusted: $M = -26.72$, $SE = 2.17$) measurements. Similar results were found when examining G2 (T5-T8) oxygenation. Specifically, a significant relationship was not found between interview condition and oxygenation during the AX-CPT task (unadjusted: $F(1, 33) = 2.110$, $p = 0.156$; adjusted: $F(1, 25) = 1.766$, $p = 0.196$), but across measurement occasions, oxygenation did differ among participants (unadjusted: $F(1, 33) = 136.135$, $p < .001$, partial $\eta^2 = 0.805$; adjusted: $F(1, 25) = 5.466$, $p = 0.028$, partial $\eta^2 = 0.179$). Participant activation in G2 increased across baseline (unadjusted: $M = 1.05$, $SD = 5.05$; adjusted: $M = 1.07$, $SD = 0.88$) and AX-CPT (unadjusted: $M = -28.70$, $SD = 13.89$; adjusted: $M = -28.62$, $SD = 2.14$) measurements.

Exploratory Analyses

Age

Initially, the present study limited recruitment to include only caregivers 65 years of age and older. To explore a subset of performance trends within this portion of the sample, study analyses were repeated on only recruited caregivers fitting this age range in the present sample.

Stress. Univariate ANCOVAs were conducted to compare unadjusted and adjusted models of stress in participants. Between participants, stress did not vary significantly based on interview condition (unadjusted: $F(1, 28) = 1.264, p = 0.270$; adjusted: $F(1, 21) = 0.524, p = 0.477$). Within participants, stress did not change across measurement occasions ($F(1, 28) = 2.281, p = 0.142$; adjusted: $F(1, 21) = 0.003, p = 0.955$), nor did interview condition affect these results (unadjusted: $F(1, 28) = 3.435, p = 0.074$; adjusted: $F(1, 21) = 1.766, p = 0.198$).

Executive Function. Multivariate ANCOVAs were conducted to compare unadjusted and adjusted models of EF performance between participants. RT and accuracy did not differ between interview conditions in either the unadjusted (RT: $F(1, 28) = 0.390, p = 0.537$; accuracy: $F(1, 28) = 2.572, p = 0.120$) or adjusted (RT: $F(1, 20) = 0.175, p = 0.680$; accuracy: $F(1, 20) = 2.349, p = 0.141$) models. Performance trends reflect those in the complete sample, with slower RT for caregivers in the experimental condition ($M = 401.12, SD = 96.99$) than caregivers in the control condition ($M = 381.16, SD = 76.95$), and higher accuracy for caregivers in the control condition ($M = 96.37, SD = 2.20$) relative to caregivers in the experimental condition ($M = 86.23, SD = 24.38$).

Cerebral Perfusion. Repeated measure ANCOVAs were conducted to compare unadjusted and adjusted models of cerebral perfusion patterns in participants. Total oxygenation did not differ by interview condition (unadjusted: $F(1, 27) = 2.364, p = 0.136$; adjusted: $F(1, 20) = 1.920, p = 0.181$), and did not differ across time within participants (unadjusted: $F(1, 27) = 0.198, p = 0.660$; adjusted: $F(1, 20) = 0.243, p = 0.627$). However, examining oxygenation

changes regardless of interview condition yielded significant changes in oxygenation in the unadjusted model ($F(1, 20) = 99.458, p < .001$), but not in the adjusted model ($F(1, 20) = 0.487, p = 0.494$). In the unadjusted model, oxygenation increased between measurement occasions (Baseline: $M = 1.14, SD = 5.78$, AX-CPT: $M = -25.19, SD = 12.12$). This mirrored that of the whole-sample analysis. G1 (unadjusted: $F(1, 27) = 2.466, p = 0.128$; adjusted: $F(1, 20) = 2.186, p = 0.155$) and G2 (unadjusted: $F(1, 27) = 2.176, p = 0.152$; adjusted: $F(1, 20) = 1.599, p = 0.221$) between-subjects oxygenation did not differ on account of interview type. Across measurement occasions, G1 (unadjusted: $F(1, 27) = 0.168, p = 0.685$, adjusted: $F(1, 20) = 0.265, p = 0.612$) and G2 (unadjusted: $F(1, 27) = 0.226, p = 0.638$, adjusted: $F(1, 20) = 0.214, p = 0.649$) did not differ on account of interview type. However, when oxygenation values across the whole sample were examined by themselves, G1 ($F(1, 27) = 87.807, p < .001$) and G2 ($F(1, 27) = 109.137, p < 0.001$) unadjusted models were significant, but their adjusted models were not (G1: $F(1, 20) = 0.395, p = 0.537$; $F(1, 20) = 0.584, p = 0.454$).

Physical Health

The present study also explored the effect of physical health characteristics on the outcome variables of interest. Preliminary analyses indicated that self-rated health, BP, and handedness were not significantly related to stress ratings, AX-CPT performance, or PFC oxygenation. However, these variables should be further investigated to parse any trends in their effects on the study outcomes. To examine the effects of these factors on post-interview outcome measures, four hierarchical linear regression analyses were conducted. In the first step, covariates from the initial analyses (age, gender, race, marital status, income, education, handedness, and lifetime duration of caregiving), and in the second, self-rated health, BP, BP medication, and handedness were included. Interview condition was included as the fixed factor.

When examining post-intervention stress, step 1 characteristics significantly contributed to the model ($F(7, 28) = 2.403, p = 0.047$). Specifically, caregiver age was significant in step 1 of the model ($t(28) = 2.988, p = 0.006$). However, health characteristics in step 2 of the model did not significantly contribute to it ($F(10, 25) = 1.535, p = 0.185$).

When examining EF performance, RT and accuracy were included as outcome variables. For RT, step 1 characteristics did not significantly contribute to the model ($F(7, 28) = 2.240, p = 0.061$). Similarly, the addition of health covariates did not significantly contribute to the overall model ($F(3, 25) = 1.442, p = 0.965$). When examining this model concerning accuracy performance, neither covariates in step 1 ($F(7, 28) = 0.800, p = 0.594$) nor health variables in step 2 ($F(10, 25) = 1.866, p = 0.100$) contributed significantly to the model.

When examining total PFC oxygenation, neither step 1 covariates ($F(7, 27) = 1.803, p = 0.128$) or step 2 health variables ($F(10, 24) = 1.151, p = 0.368$) significantly contributed to the model. Examining G1 and G2 oxygenation, neither step 1 covariates (G1: $F(7, 27) = 1.552, p = 0.193$; G2: $F(7, 27) = 2.043, p = 0.086$) nor step 2 health variables (G1: $F(10, 24) = 0.989, p = 0.479$; G2: $F(10, 24) = 1.317, p = 0.227$) were significantly implicated in the model.

Chapter 4: Discussion

The purpose of this study was to examine the effects of recalling caregiving stress on EF performance and its underlying neural correlates in a sample of caregivers. Three research questions guided the study and its methodology:

1) Does recalling stressful caregiving experiences increase participants' self-reported stress?

- 2) Do caregivers perform worse on an EF task after completing an interview about stressful caregiving experiences relative to caregivers who completed an interview about a neutral topic, such as their hobbies?
- 3) Do caregivers who participate in the caregiving stress interview demonstrate reduced PFC oxygenation while completing the EF task?

The results indicate that self-reported stress did not differ across measurement occasions (baseline versus post-interview) in caregivers, and self-reported stress did not differ as a function of interview type. However, an interaction between arousal scores and interview type was present; higher arousal scores between measurement occasions were associated with the control condition (hobby interview). Second, while assessing cognitive performance, caregivers did not differ based on interview type for RT or accuracy when taking the AX-CPT. Duration of caregiving activities across the caregiver's lifetime was significantly associated with longer RTs and lower accuracy scores but this relationship was not observed between experimental conditions. Finally, when examining fNIRS oxygenation data, PFC oxygenation did not significantly differ by interview condition, but all participants demonstrated an increase in PFC oxygenation between measurement occasions.

Caregiver Stress

Caregivers assigned to the experimental condition did not differ in self-reported stress from those assigned to the control condition. In other words, recalling stressful caregiving experiences did not significantly increase participant stress levels. This was contrary to the study's hypothesis that self-reported stress scores would increase from baseline to post-interview in caregivers who recalled stressful caregiving experiences. Previous studies have demonstrated

the stressful nature of caregiving (Ozkan Tuncay & Kars Fertelli, 2019; Sheehan et al., 2021; Vitaliano et al., 2003), and studies rethinking symptomology in persons with PTSD have highlighted the dynamic nature of individual stress responses (Mathew et al., 2022; Nilaweera et al., 2020; Verwoerd et al., 2009). However, there could be several explanations for why this hypothesis was not confirmed, including study methodology and environmental and interpersonal factors related to stress response processes.

Regarding study methodology, self-reported stress was measured at two time points using the Stress-Arousal Inventory: 1) at the start of the study (baseline) and 2) near the end of the study after undergoing the interview condition and AX-CPT. The results indicated that caregivers assigned to the experimental condition reported higher, but non-statistically significant, baseline stress levels than caregivers assigned to the control condition. However, changes in stress levels were not seen across measurement occasions; these levels were not correlated with any outcome variables and were not significant in the model. Thus, although differences in self-reported stress existed between groups, they likely did not affect the measurability of change in the analyses. However, the timing of the second stress-arousal measurement may have impeded the ability to measure certain aspects of the stress response. This measurement was placed after the completion of the AX-CPT task, not after the completion of the interview in the study protocol. This was intentional, as the current study was most focused on behavioral and neural outcomes. However, this may have instead measured stress associated with completing the AX-CPT task itself and quite possibly diluted the stress response evoked from the interview. Though stress ratings did not significantly differ across measurement occasions for caregivers, this may be masking any stress responses experienced by the experimental group following their interview. With the average stress response lasting between

20-60 minutes in humans (Kleshchova & Weierich, 2021), stress generated from the onset of the interview may be lessened by the end of the AX-CPT task, as these tasks lasted about 20 minutes in total.

This may also explain the significant arousal score findings. An interaction was found between the interview condition and arousal score; caregivers in both groups experienced increased arousal scores across measurement occasions, but caregivers assigned to the control condition reported significantly higher arousal scores. Caregivers in both groups likely experienced an increase in arousal due to the engaging nature of the AX-CPT, but caregivers assigned to the experimental condition may have already experienced an increase in arousal due to the nature of their interview condition. However, this cannot be confirmed in the present study due to the placement of arousal measurements. In this case, the control group may have experienced the greatest change in arousal between measurement occasions as their interview may not have increased arousal compared to the emotionally charged topic of the experimental condition. In other words, caregivers in the experimental condition may have adapted to higher levels of stress and therefore changes are less pronounced when a stressful stimulus is presented. Thus, the difference in arousal would be less among the experimental group versus the control group.

It is also possible that the experimental condition did not successfully induce stress in the present study. This reasoning would explain the non-significant relationship between self-reported stress and interview type. If recalling stressful caregiving experiences was not enough for participants to experience a change in stress levels (or at least enough change to be measured), then non-significant differences between experimental groups would be explained. This would also help to make sense of why alterations in cognitive performance and oxygenation

did not differ by experimental condition. If participants in the experimental group did not experience increased stress after their interview, or this stress remained consistent during the session, decrements in cognitive performance or PFC oxygenation would likely not be seen.

To further examine stress induction in caregiver populations, alternative stress-induction protocols could be utilized. A variety of stress tests have already been used in aging research, including the use of the Trier Social Stress Test (TSST) (Allen et al., 2016), simulations like a virtual driving test (Mather et al., 2009), and memory tasks like the 2-back (Luers et al., 2020) and digit span test (Pulopulos et al., 2015). However, caregiving stress is multifaceted, including both acute and chronic elements (Brown et al., 2014; Vitaliano et al., 2003). Thus, paradigms using caregiving-specific stressors may better inform how this type of stress affects caregivers.

Implementing stress paradigms in research studies calls for ways to balance participant safety with research objectives. It may be possible to do so using dyadic or home-based research strategies. Dyadic research allows the caregiver and the care recipient to participate in a research session (Irani et al., 2022). Because many care activities limit the availability of caregivers to participate in research, dyadic and at-home methods would allow caregivers access to their care recipients during the study session. It would also allow studies to examine caregiving contexts and relationship elements that affect caregiver outcomes. Previous studies have utilized dyadic methods to examine caregiving stress and have found underlying dynamics to be influential in the stress process (Hausler et al., 2016; Goodwin et al., 2013). Hausler (2016) utilized a population of spousal caregivers to study the relationship between stress and quality of life. They found dyadic coping mediates the relationship between stress and quality of life in this sample of caregivers. Similarly, Godwin (2013) examined the effect of mutuality, a concept broadly associated with closeness in a relationship, in caregivers and their care recipients who survived a

stroke. Their findings suggest a significant relationship between spousal caregivers and perceived stress, such that caregivers were significantly more affected by interpersonal and care recipient stress than their care recipient (Godwin et al., 2013). These studies provide researchers a route to examine relationship dynamics, specifically targeting points of contention within the care relationship. This would allow for the measurement of stress-related outcomes within an ecologically valid setting and could be introduced with an intervention to attenuate the negative effects of discussing potentially stressful topics. Alternatively, researchers could enter the home of a participant (or whatever facility type that the caregiver and care recipient interact in) and observe stress as it naturally arises in that environment. Although both of these scenarios come with their own set of issues and limitations, such as the presence of environmental confounds, they provide alternative means to study caregiving stress while ensuring ethical practices.

Other interpersonal factors may also explain the absence of stress differences in the sample, including those rooted in individual biology and genetics. In caregiving research, gender is associated with differences in stress response and subsequent outcomes in caregivers (Penning & Wu, 2016; Sharma et al., 2016). It also serves as a moderator of this relationship (de Vugt et al., 2006; Lee et al., 2004; Pertl et al., 2017; Vitaliano et al., 2009; Vitaliano et al., 2017). Bueno's (2023) and Swinkels' (2019) findings demonstrate this relationship, with heightened stress responses being observed in female caregivers, especially when accounting for secondary stressors like relational problems, financial issues, and conflicting tasks. Swinkel (2019) further suggests that in certain situations, heightened stress responses in male caregivers are also present. This response is also higher when care intensity and primary stressors are more prevalent, such as in scenarios where the care needs of recipients conflict with the needs of caregivers. In the current study, gender was correlated with baseline stress scores, but it was not

associated with change across measurement occasions or in the context of caregiving activities. These findings align with previous work suggesting an association between gender and stress response, but not necessarily those that connect gender and stress response in caregivers specifically.

Variations in genes related to the nervous system and HPA axis functioning, as well as those involved in inflammatory responses, are associated with alterations in bodily stress responses (Ising & Holsboer, 2006). Alterations in these genes have been implicated in several clinical disorders such as coronary artery disease, depression, and bipolar disorder (Ising & Holsboer, 2006). These findings are likely related to the release of cortisol and corticotropin hormones, which are often altered in the presence of depression and bipolar disorder (Pariante et al., 2004). In other clinical populations, such as people diagnosed with PTSD, overactive dopamine transporters have also been implicated in its pathology (Drury et al., 2009; Li et al., 2016; Valente et al., 2011). Specific to rethinking, Apolipoprotein E (ApoE) is a mechanism implicated in this symptomology, as it controls neural and glial stress response in the body and has been associated with increased cortisol concentrations and rethinking symptoms in combat-exposed veterans (Peterson et al., 2015). Peterson (2015) found the PTSD re-experiencing symptoms to be related to the number of cysteine residuals per mole in ApoE.

Although genetically based stress responses were not examined in the current study, some caregiving studies have provided insight into biologically based stress responses. For example, depression symptoms and alterations in sleep and pain symptoms have been evaluated by researchers. Wolf (2018) examined caregiver depression risk and found that caregiver genetic risk scores were associated with increased susceptibility to experiencing depression symptoms in family caregivers of older adults. Wilson (2019) observed that caregivers who carried specific

types of serotonin alleles (such as short-allele carriers for 5-HTTLPR and rs6295 C) experienced more pain and sleep problems, as well as overall distress levels, compared to other individuals who did not carry this allele. This was also present for rs6295 C carriers. Signaling pathways that regulate inflammation in monocytes have also been implicated in caregiver stress response. For example, in caregivers of persons with glioblastomas, caregiver monocytes showed higher expressions of pro-inflammatory-related genes and lower expressions of anti-inflammatory-related genes (Miller et al., 2014).

These factors are necessary to consider as they may play a role in participant stress experiences in the current study. For example, caregivers who were recruited for the study varied by demographic, health, caregiving, and physiological characteristics. Each of these variables was identified at the beginning of the study and examined using correlation analyses to identify any potential relationships between them and the study outcomes. Those that demonstrated significant relationships with the outcomes were included in the model as covariates. As reported in studies by Wolf (2018), Wilson (2019), and Miller (2014), genetic variability between individuals may also be related to their stress responses in caregivers. If caregivers in the present sample varied in their genetic makeup, such that some caregivers carried either the 5-HTTLPR or rs6295 C allele (Wilson et al., 2019) while others did not, this could impact how they responded to the experimental condition. Perhaps caregivers in the present study did not carry either allele, which contributed to non-significant changes in stress across the study. Or, perhaps caregivers in the sample were relatively distributed in the presence and absence of these alleles, which negated the effects of higher stress responses in some caregivers. When not accounted for, these questions cannot be tested. In sum, these unaccounted factors may help explain the results found in this sample and in the broader literature where caregiver stress outcomes vary.

How individuals perceive and cope with a stressor is also important to consider when examining stress responses. Especially in stress research, coping strategies influence responses to stress stimuli (Ding et al., 2021). Caregiving stress research has identified an association between coping styles and stress responses, such that coping styles can reduce psychological distress (Gilhooly et al., 2016), and benefit mental health (Li et al., 2023) and physiological outcomes (Kim et al., 2007; Peyrot & McMurray, 1992). More specifically, avoidant or indirect coping styles are associated with poorer physical health ratings in caregivers, and conversely, proactive coping styles (i.e., positive appraisal) are associated with better physical health ratings in caregivers (Kim et al., 2007; Peyrot & McMurray, 1992). In PTSD research, rethinking and other forms of intrusive thoughts also demonstrated relationships with coping strategies; resilient coping strategies were associated with decreases in re-experiencing and intrusive thoughts across a 2-year time period (Sinclair et al., 2020).

In the present study, coping strategies were not directly measured, which may have hindered additional insight into the cognitive and neural findings identified here. Because previous caregiving literature has identified differential stress responses among caregivers using coping strategies, it is possible that these strategies influenced how they responded to recalled caregiving stressors in the current study. For example, Gilhooly (2016) suggests caregivers who utilize coping strategies experience reductions in psychological stress and negative physical outcomes. For caregivers undergoing the experimental interview condition, the use of coping strategies may have influenced caregiver stress responses, potentially lessening their stress ratings and allowing for maintained or improved performance on the AX-CPT. Alternatively, coping may have negated the physiological responses associated with stress as found by Kim (2007) and Peyrot (1992). This may help to explain why differences in PFC oxygenation were

not found in the current study. It may be that utilizing coping strategies when exposed to an immediate stressor, such as the experimental condition in the present study, helped to negate the effects of stress on the caregiver, thereby protecting against alterations in oxygenation.

Alternatively, a cumulative effect of coping with caregiving stressors may have helped attenuate this response over time, though an interaction between lifetime caregiving and PFC oxygenation was not found. In sum, controlling for the effect of coping strategies when measuring outcomes in the face of caregiving stress may help clarify this potential relationship.

AX-CPT Performance

RT and accuracy differences were not observed between experimental groups on the AX-CPT. As described previously, one reason for this may be due to the stress-induction protocol utilized in this study. Contrary to the study's hypothesis, caregivers did not report an increase in stress after undergoing the caregiving stress interview. This may be due to the experiences each caregiver recalled during the interview, such that these experiences did not elicit a stress response or one that led to alterations in their cognitive processes. Previous studies have uncovered the lingering effects of stress recall on individuals, including children (Gittens et al., 2015), young adults (Sales et al., 2005), and older adults (Hidalgo et al., 2014). These studies included successful stress-induction paradigms (i.e., self-reported stress increased from baseline), and observed poorer memory (Sales et al., 2005) and recall (Hidalgo et al., 2014), as well as increased psychological symptoms like anxiety (Gittens et al., 2015). However, our findings do align with those of Stone (2021), which suggests that even after the implementation of a successful stress protocol, significant effects of stress on the Attentional Network Test were not found. Although differences in stress were not found in the present study, Stone's (2021) findings call into question whether stressors, such as caregiving-related stress, to alter attentional

processes, like those measured by the AX-CPT. However, it may be that the measure utilized in Stone's (2021) study was not sensitive enough to detect changes in attention even with a successful stress induction paradigm.

Significant differences were apparent when the focus shifted to comparing lifetime durations of caregiving activities and cognitive performance. The current study observed slower average RT (i.e., more time to complete tasks) for caregivers who had longer lifetime caregiving durations compared to those who had shorter durations, and this finding was not influenced by interview type. When examining specific trials within the task, this relationship remained for AX, AY, and BY trials, but not BX. In terms of accuracy performance, caregivers did not significantly differ in total accuracy on the task, but caregivers who reported longer lifetime durations of caregiving activities performed better (i.e., more correctly) on BX trials. This was not seen for AX, AY, or BY trials.

This may be related to the speed-accuracy tradeoff (SAT) (Vandierendonck, 2021), which defines the choice participants must make between answering slower and making fewer errors or answering faster and being at risk of making more errors. In older adults, this pattern of behavior is more prevalent, with some research pointing to age-related deficits in neural performance (Brinley, 1965; Salthouse, 1996) and others pointing to older adults' overall reluctance to commit errors (Salthouse, 1979; Starns & Ratcliff, 2010). In the current sample, caregivers, whose ages averaged around 56 years, and had performed caregiving activities for longer periods, answered more slowly on the AX-CPT, suggesting that their willingness for speed was not chosen over their desire to answer correctly. However, their accuracy performance was not affected. Although the present sample did not meet the standard threshold for older adulthood, which is often characterized as 65 years and older, the lack of accuracy finding may

be an artifact of this age gap. Specifically, caregivers approaching older adulthood may be experiencing components of the SAT, such as slower RT, without experiencing its other effects, such as the increase in accuracy. Prior research supports this pattern of findings, suggesting that better performance on speed tasks by answering slower only minimally improves accuracy scores (Forstmann et al., 2011). However, this pattern requires additional examination to track SAT across the lifespan.

The SAT is related to the strategies individuals can use on the task, specifically referred to as proactive and reactive control strategies (Braver, 2012). Proactive control refers to the strategy of holding relevant information until an action is completed, whereas reactive control waits until a stimulus (in this case, the “A” cue) is presented and then responds (Braver, 2012). Caregivers with longer lifetime caregiving durations exhibited slower RTs on AX, BY, and AY trials and higher accuracy on BX trials. This follows reactive control responses to some degree, such that slower response times were seen on AX trials, however no differences in RT were found on BY or AY trials. More so, performance on AY trials was slower, which goes directly against the typical response patterns seen in reactive control. In terms of accuracy, these findings were also puzzling. On one hand, higher accuracy on BX trials is consistent with proactive control, but this goes directly against reactive control behaviors. Thus, participant responses do not demonstrate enough evidence of either control type to accurately label it. It may be that participants used both control strategies when completing the task, which would explain some of the consistencies observed with both types of control. It may also be that the study was too underpowered to detect accurate patterns of behavior in the task, and a larger sample size might produce a more distinct response pattern in caregivers.

These results were similar to those found by Husa (2022), which tested differences in cognitive control between young adults after undergoing an induced stressor. No differences in either RT or accuracy between the control group and the experimental group were found whether examining overall scores or trial-specific scores. In the current study, this was a similar outcome, such that differences were not found between the experimental group, which underwent a stress recall interview, and the control group, which talked about a neutral topic like hobbies. However, in Husa's (2022) study, the effect of their stress paradigm did significantly alter self-reported stress levels in participants in the experimental group and the current study's did not. This may be due to a more effective stress induction program than used in the present study. Husa (2022) utilized the Trier Social Stress Test (Kirschbaum et al., 1993), a psychological test involving anticipation and testing periods designed to induce stress within users. While the present study induced stress by asking caregivers to recall stressful caregiving experiences, Husa (2022) asked participants to give a speech and perform arithmetic in front of an audience. Although recalling stressful experiences may be distressing to caregivers, it is possible that reflecting on past experiences does not elicit the same level of stress as the initial event or when asked to perform tasks in front of an audience.

Differences may also stem from variances in sample populations. In the current study, caregivers, a population that experiences chronic and acute stressors in their everyday caregiving activities, were utilized whereas Husa (2022) used non-caregiving young adults. The differences in stress exposure between these groups may contribute to the differences seen here as recalling a stressful caregiving experience may not be enough to evoke stress in the current study's sample, but undergoing a stress paradigm in a non-caregiving population did. Interestingly, differences in AX-CPT performance persisted across our sample without the effect of the stressor. It may be

that existing stress levels of caregivers were already enough to influence their performance on the AX-CPT, or it could be that undergoing the stressful caregiving interview did not increase these levels in participants because the threshold for change was already reached (or remained relatively stable).

Environmental and participant-level factors may also influence response strategies and performance. In terms of the environment, some research suggests an influence of experimental versus non-experimental settings on RT and accuracy performance. For instance, Domingue (2022) observed marginal increases in RT that did not necessarily increase response accuracy, while other findings observed decreases in response accuracy (Simons, 2000), and in others, a curvilinear relationship emerged (Chen et al., 2018). This may be due to changes in goal orientation, such that after some time, participants are subject to mind wandering (Smallwood and Schooler, 2015) or changes in time pressure within the setting (Heitz, 2014). In the current study, caregivers often scheduled their session around the activities of their care recipient, so it is possible that when participating in this task near the end of their session, caregivers may have begun to think about their impending caregiving responsibilities. Similarly, participants who scheduled an at-home session may be less distracted throughout the session because they could tell if their care recipient needed assistance. In the present study, caregivers who had in-home study sessions were not interrupted during the interview or AX-CPT portions of the protocol. However, some participants did require short breaks during their sessions to attend to the needs of their care recipient. These deviations in protocol likely introduced variance in both cognitive performance and PFC oxygenation. In the present study, increases in RT, but not accuracy, were demonstrated in participant AX-CPT performance. This aligns with Domingo's (2022) findings, which pose a question of effect in this sample. This may help to explain why some findings

aligned with proactive and reactive control strategies, as differences in mental state may have influenced performance strategies.

Also consistent with the present study, Domingue (2022) found inconsistent relationships between respondent speed and ability. Specifically, faster responding was not always associated with increased accuracy. A specific subgroup in their sample, older adults, was more consistent, with increases in RT associated with decreases in accuracy, which is consistent with other findings suggesting a change in the SAT (Heitz, 2014; Salthouse, 1979) with age. While this pattern may be present in the current study, it is difficult to assess given the wide range of ages in the sample and its underpowered design. However, exploratory analyses trend in the direction of Domingue's (2022) results, with older adults experiencing longer RTs than adults under the age of 65; no significant differences were found in accuracy performance. Thus, our findings may demonstrate more credence to the SAT, but further examination is required.

Neural Correlates

In the current study, change in PFC oxygenation was not associated with either experimental condition, however, PFC oxygenation did increase across all participants between baseline and the post-interview measurement. Increases between baseline and the cognitive task are consistent with an increase in cognitive demand (Kim et al., 2013), though the lack of change between interview conditions went against the study's initial hypothesis. Previous research indicates an increase in neural responses as a result of undergoing stressful events or stimuli (Meier & Schwabe, 2024), with chronic stress eliciting reductions in neural response over time (Arnsten et al., 2015). As such, it is somewhat surprising that caregivers who recalled stressful caregiving experiences did not demonstrate any significant changes in PFC oxygenation, whether increasing or decreasing.

Reasons behind this result may include those mentioned previously like lack of stress induction from the experimental condition and an underpowered sample. In the case of a lack of stress induction, non-significant change between interview conditions would be understandable. If no stress occurred, then no change should occur besides that already present between baseline and the EF task. On a similar thread, caregivers may be desensitized to stress stimuli, so attempts to induce acute stress are less effective or not effective at all. However, there may be several other plausible reasons that may also explain this finding (or lack thereof).

First, fNIRS technology is specifically designed to image the cortical surface, which means that internal brain structures are largely missing from their detection (Liu et al., 2015). In the current study, the PFC is specifically of focus due to the EF domain being examined, which is housed primarily within the PFC. Several studies situate cognitive processes utilized in continuous performance tests in the PFC region, specifically in the dorsolateral PFC, ventrolateral PFC, and ventromedial PFC (Braver et al., 2009; Krug & Carter, 2012; Nee & Brown, 2012). However, another structure, the anterior cingulate cortex (ACC) is also implicated in these processes and lies interior to the PFC, closer to the center of the brain (Braver et al., 2009; Krug & Carter, 2012; Nee & Brown, 2012). Both the PFC and the ACC are implicated in responses to emotional stimuli such as increasing activation of the ACC in response to fearful faces (versus neutral) on an attentional task (Monk et al., 2003), and increased activation in the ventromedial PFC during a negative condition (compared to neutral) in a go/no go task (Lamm & Lewis, 2010). fNIRS technology is only able to capture the activations present in the cortical surface, such as the PFC, but not the ACC. This is particularly important in the current study as participants in the experimental group were exposed to an emotional stimulus that also may be considered stressful. Particularly, if activation increases in the ACC in the context of the

experimental condition, it leads to questions regarding whether this effect was present in the current study. Although the PFC did not exhibit significant change in activation, it may be plausible that the ACC experienced change and it was unable to be measured.

Change in activation in the ACC is particularly interesting due to its connection to PTSD etiology (Hinojosa et al., 2019; Young et al., 2018). Researchers in this field speculate that the ACC is entangled with the onset and maintenance of the disorder (Hinojosa et al., 2019). More specifically, PTSD populations exposed to distressing stimuli have demonstrated lower activations of the ACC compared to healthy controls (Bremner et al., 1999; Shin et al., 2001) as well as increased BOLD signals in the left ventral and dorsal ACC when recalling negative word stimuli (Thomaes et al., 2013). In the current study, the use of emotional stimuli, like caregiving stress, may also target the ACC, but the current methodology is unable to capture any changes seen there. This is a potential avenue for future research on neural correlates of caregiving stress and may benefit from the use of fMRI to assess the changes occurring within these internal structures.

In caregivers, the role of the ACC in stress and emotional stimuli responses is largely understudied. In one extant study by Inagaki (2016), the role of the ACC in adults providing support to others was examined. Their findings suggest reductions in stress mechanisms when giving support and increased activity in goal-related regions, specifically the dorsal ACC. However, it is important to consider the differences in care intensity between this study and the present one. Participants in Inagaki's (2016) sample were tested on a measure of support and were not explicitly caregivers, whereas, in the current study, caregivers were specifically targeted. Differences between these groups are related to the intensity of support as well as the support activities, such that caregivers in the current sample participated in more frequent and

intense activities compared to those in Inagaki's (2016) sample. Thus, although this study demonstrates the role of the ACC in stress response when caring for others, it may not be the most accurate representation for caregivers who provide more intense and frequent care.

Although studies implicating the PFC and ACC in stress and emotional stimuli responses, other areas of the brain are also implicated in these responses. Structures like the hippocampus and amygdala are implicated in stress response, specifically those associated with emotion-related memory processes like rethinking. Like with the ACC, these structures reside in the internal parts of the brain, which cannot be detected by fNIRS. The hippocampus and amygdala are associated with the risk of developing PTSD as well as maintenance of the disorder (Morey et al., 2012). In several studies examining these structures, decreased volumes were found (Karl et al., 2006; Morey et al., 2012; Woon et al., 2010). Specifically in rethinking symptomology, the hippocampus and amygdala are associated with functions relating to emotional regulation, fear learning, and processing (Ben-Zion et al., 2024). In the amygdala, hyperactivity of glucocorticoid receptors as well as increased amygdala response to emotional stimuli was found (Etkin et al., 2007; Morey et al., 2009; Murrough et al., 2011). In caregivers, the examination of these structures in rethinking is relatively non-existent, with most studies examining the emotional responses of caregivers more generally (Freedman et al., 2022; Li & Murray, 2015; Roth et al., 2009). In one extant study by Correa (2018), the mental health of caregivers of people with ADRD was examined. Although the amygdala was not studied, hippocampal dysfunction was present in conjunction with contextual memory impairment. Taken together, fNIRS only measures the cortical surface and does not measure oxygenation of internal brain structures related to the stress process like the ACC, amygdala, and hippocampus (Liu et al., 2015). Although changes in oxygenation were not observed in this study, which focused on the

PFC, changes in oxygenation of the internal structures implicated in the stress response may have a role in caregiver stress response.

The current study's design was underpowered, and thus, may not be sensitive enough to detect smaller, more transient changes in cognition. Specifically, the current study utilized a block average design, which examined changes that occur over the duration of the cognitive task or within a specified period of the task (Amaro & Barker, 2006). In the AX-CPT, participant performance was modulated into individual trials and blocks of trials, which was then transformed into an average across the overall task and particular trial types (AX, AY, BX, BY). This averaging allowed for investigation into participant performance over time but did not allow for examination of transient effects. To utilize an event-based design in the present study, targeted effects, like those happening in the moments following the presentation of target stimuli, would be measured. Implementing more specific measurement occasions may have elucidated specific changes in RT, and allowed further examination into response patterns in the sample. Additionally, the neural measures in the task (i.e., oxygenation in the PFC), were averaged into one value for the entirety of the task. This likely masked smaller, specific changes in oxygenation that may have occurred at specific task points, such as during specific trial types or periods of the task, which would also be captured by utilizing an event-based design. For example, when participants began the AX-CPT, their responses were more likely to be influenced by effects elicited from the experimental interview than later on in the task. With the current design, the changes exhibited at the beginning of the task are averaged across the entirety of the task, thus diluting its effects. As such, relating changes in AX-CPT performance, such as accuracy and RT, to neural activity is much harder given the muddling that occurs with block-

average measurement of oxygenation. If utilizing an event-based design, these periods would be specifically measured and examined in the context of the trial block and the overall task.

Studies outside of caregiving and PTSD literature provide more insight into the effects of research design on cognitive outcomes. For example, Chee (2003) examined differences in the word-frequency effect while comparing block versus event-based fMRI designs. Although similar brain regions were activated on both task types, the amplitude of block design results was lower than those of event-based results. Similarly, Tie (2009) examined activity in language areas in both healthy controls and patients with tumors near language cortical areas and found higher activations in these areas using an event-related design compared to a block design. Although these studies are not specific to the population in the current study, they do highlight the issue of sensitivity within the study design and identify an important consideration for future work on the topic.

Connecting Pearlin's Stress Process Model

Pearlin's (1990) Caregiver Stress Process Model combines contextual, societal, and interpersonal factors and applies them to caregiver outcomes. The present study does this by examining caregiver demographic, health, and caregiving activities in the context of executive function performance on the AX-CPT and its underlying neural correlates. Previous studies have elucidated the effects of caregiving stress on cognitive domains, but this theory remains largely underrepresented in experimental caregiver studies.

The present study found an effect of lifetime duration of caregiving experience on AX-CPT RT performance. This relationship persisted even when accounting for additional covariates that have been previously identified as influential to caregiver outcomes in other studies using

Pearlin's model (García-Castro et al., 2022; Kim et al., 2007; Penning & Wu, 2016; Pinquart & Sorensen 2003, 2005; Sharma et al., 2016; Vitaliano et al., 2003). Although the present study only utilizes Pearlin's (1990) model as a framework for the study, current findings suggest that caregiver experiences across time is related to EF outcomes later in life. Additional studies should seek to apply this model in experimental applications to test its tenets.

Strengths and Limitations

The current study has several strengths including its novel research question and methodology that combined both behavioral and neurophysiological measures. The study is the first of its kind to examine the effect of recalling stress in caregivers, which is an experience common in caregivers and other clinically stressed populations like PTSD. This provides insight into the stress experience of caregivers, one that extends beyond self-report measures. It also allows for the relationship between shared clinical symptoms to be explored, specifically between intrusive memories or “re-thinking” experiences in PTSD and caregiving. No other study has examined this potential relationship, especially using behavioral and physiological measurements. The study also provides a look into the cognitive and neural processes impacted by caregiver stress responses. Previous literature has examined cognitive performance, specifically EF, in caregivers, but this examination is more general, without the impact of momentary stress experiences. As EF is essential in many caregiving activities, it is important that these functions are assessed within proximity to the stressful event to examine its impacts. Additionally, fewer studies exist that examine cognitive performance in caregivers utilizing neuroimaging technology, specifically fNIRS. This technology provides useful insight into the underlying neural correlates involved in cognitive processes, which gives insight into physiological responses to stress. fNIRS technology is specifically designed to be more dynamic

and less sensitive to movement, which gives researchers access to caregiving outcomes without restrictions imposed by other imaging technologies like fMRI. While assessing PFC oxygenation in caregiving stress, in-vivo research in the daily lives of caregivers is possible with this technology.

However, several limitations are present in the current study that should be noted. These include recruitment challenges, sampling issues, and methodological limitations. Recruitment of caregivers for the study was extremely difficult, even with the inclusion of another state for recruitment. The 36 caregivers included in the sample took 1 year to recruit and required many outreach efforts including digital and paper advertisements as well as cold calling to local businesses and medical offices. It is likely that many of the caregivers that agreed to participate in the study were caregivers whose recipients were more independent, and thus required less help. For example, BALDS scores averaged at 21 out of a total of 60 for care dependency, meaning that care recipients' levels of dependence are lower. As such, the current study may have examined stress in a group of caregivers that may not experience as much stress as caregivers who provide care to recipients with greater needs and is likely underpowered to detect more subtle effects. This may be why the results of the study were non-significant between groups. Additionally, in order to recruit the current sample, a broader caregiver net was cast during recruitment. This included a broader age range, recipient diagnosis, and caregiver type (i.e., formal versus informal). As many caregiving studies use a specific population of caregivers (i.e., ADRD caregivers, cancer caregivers), the inclusion of a more diverse sample may contribute to the lack of effects found here. Specifically, differences in types of care activities and intensities are common amongst caregivers of recipients with different ailments, and this

may have generated more heterogeneity in the sample, masking the effects that may be present in a specific group of caregivers.

The use of a block design to measure changes in cognition may have also contributed to our results. Block designs may be less sensitive to changes in cognition because it measures cognitive change over time as opposed to trial-based responses. An event-related design, or a design that measures changes immediately around a specified trial, may be more sensitive to changes that occur shortly before or after engagement in a cognitive task. In the current study, it may be that stress effects across time are below the threshold of measurement, but the potency of their effects may be measurable specifically around each trial.

Future Directions

The number of individuals providing care to older adults will continue to grow in the upcoming decades. Many Americans will be entering into a system that may not have the structural support needed to provide or sustain care for all those in need. Understanding the effects of providing care to an older adult, especially in a system that lacks the required numbers and knowledge needed for this care, is imperative as many caregivers are already exhibiting adverse emotional, psychological, and physiological outcomes. Future research should continue to examine these outcomes in caregivers, especially their EFs, as many facets of cognition are required for caregiving activities.

In the present study, sampling and methodological issues challenged the measurement of caregiver stress outcomes. Recruitment took place in an area largely comprised of college-aged adults, which challenged the study's ability to find caregivers, especially those who were eligible and willing to participate in the study. A large proportion of caregivers in the sample belonged to

a homogeneous group of white, highly educated, and higher-income individuals. As such, it was difficult to apply observed behavior patterns to the larger population of caregivers who are a diverse group of individuals. However, heterogeneity did appear in the sample in terms of caregiver ages and the nature of their care recipient's needs. Because recruitment challenges were present, targeting a specific age group of caregivers (i.e., caregivers over the age of 65) or care needs (i.e., caregivers of persons with memory needs) was not feasible for this study. Thus, caregivers in the present sample varied widely in age and care recipient needs. As demonstrated in caregiving stress literature, demographic and caregiving factors likely play a role in caregiver outcomes. In the present study, changes to recruitment strategies and recruitment locations would allow for a larger, more diverse caregiver population to be reached. This could be achieved by partnering with medical institutions, nursing homes, and residential care networks. Although recruitment from these nursing homes and residential care facilities was attempted in the present study, this was informal in nature. The induction of more formalized recruitment programs or sponsorships from these facilities may increase the willingness of staff and family members of residents to participate.

Changes to study methodology would also improve the measurement of study outcomes. In the present study, the stress-induction protocol did not elicit changes in caregiver stress levels. As such, altering the stress-induction paradigm may elicit this response in caregivers in future studies. This could involve utilizing stress-induction strategies that do not draw on caregiving factors. However, the use of these more general induction methods may not capture the unique stress responses experienced by caregivers. Arithmetic tasks and driving simulations have successfully been used to induce stress, so the present study could alter its paradigm to include one of these methods to raise caregiver stress levels before participating in the AX-CPT.

However, this would not assess caregiving-specific stress, only task-related stress, on caregiver EF outcomes, which may not capture the underlying dynamics associated with care-related stressors.

Other methodological changes would also improve the study's ability to measure caregiver stress outcomes. Specifically, changing the measurement design to include an event-based protocol and utilizing neuroimaging technology that measures deeper cortical structures would allow for more transient effects of stress to be measured. As demonstrated in previous cognition studies, the use of block designs may not be optimal for assessing momentary stress effects. In the present study, event-based measurements would provide insight into the changes occurring at specific trial points in the AX-CPT whereas block designs only provided information about the average change that occurred across the task. Similarly, the use of fNIRS in the present study may not have captured change occurring in deeper cortical structures during the AX-CPT. Previous studies examining rethinking in PTSD populations cite the roles of internal structures like the ACC, hippocampus, and amygdala in stress response. Although fMRI has its own limitations, such as high equipment costs and movement restrictions, it can measure deeper cortical structures such as these. Changing to this neuroimaging technology in the present study would provide information about whether these structures experienced changes after recalling caregiving stress, which would allow furthering understanding about these mechanisms. Together, these changes would improve the interpretation of the study findings, especially in the context of cortical oxygenation and EF performance.

Conclusion

The current study aimed to address a gap in caregiving literature related to caregivers' stressful caregiving experiences. Specifically, the study examined whether recalling stressful

caregiving experiences influenced cognitive performance on an EF task; neural correlates of this potential effect were also examined. While recalling caregiving stress did not influence cognitive performance on an EF task nor provide insight into potential neural correlate differences, the amount of time a caregiver spends caregiving across their lifespan significantly influenced RT on the cognitive task. This supports previous research that suggests alterations in EFs among caregivers of older adults. However, due to recruitment and methodological limitations, further investigation into this relationship is required. Improving recruitment strategies, strengthening the stress-induction paradigm, and utilizing an event-related design and more expansive imaging technology will aid in detecting these cognitive changes in caregivers.

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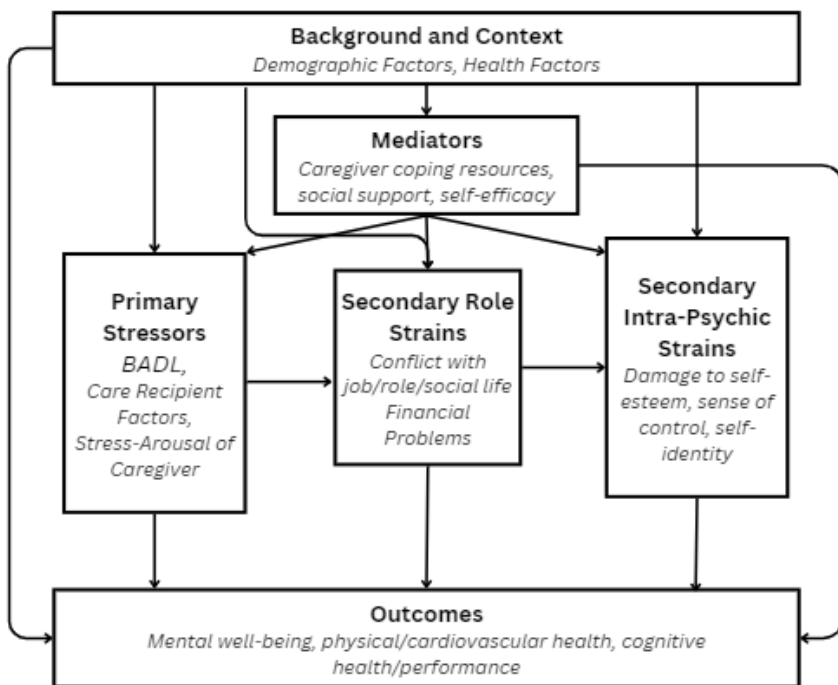
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Appendix A

Figure 1

(Modified) Caregiving Stress Model (Pearlin et al., 1990)

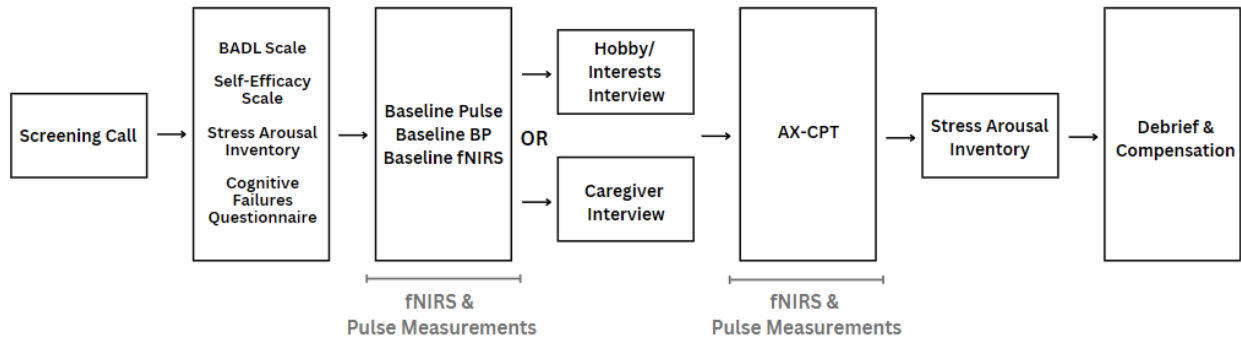


Note. This model is adapted from Pearlin's (1990) Caregiving Stress Model and includes variables specific to the current study.

Appendix B

Figure 2

Study Procedure



Note. This figure depicts procedures in the current study. This study consisted of two parts: 1) a pre-session phone call (i.e., “Screening Call”), and 2) an in-person session conducted in a research lab or at the participant’s home.

Appendix C

Table 1

Caregiver Demographic Characteristics By Interview Type

Baseline Characteristic	Full Sample N = 36			Hobby Interview N = 18			Caregiving Stress Interview N = 18		
	<i>n</i>	%	<i>M(SD)</i>	<i>n</i>	%	<i>M(SD)</i>	<i>n</i>	%	<i>M(SD)</i>
<i>Demographics</i>									
<i>Gender</i>									
Male	9	25		4	22.2		5	27.8	
Female	27	75		14	77.8		13	72.2	
Age	36		57.61 (15.82)	17		55.39 (15.66)	18		59.83 (16.11)
<i>Race</i>									
Black/African American	1	2.8		1	5.6		0	0	
White/Caucasian	21	58.3		9	50		12	66.7	
Asian	2	5.6		1	5.6		1	5.6	
Middle Eastern	12	33.3		7	38.9		5	27.8	
<i>Ethnicity</i>									
Non-Hispanic/Latino	36	100		18	100		18	100	
<i>Highest Level of Education</i>									
High School	2	5.6		0	0		2	11.1	
Some College	2	5.6		1	5.6		1	5.6	
Associate's degree	2	5.6		1	5.6		1	5.6	
Bachelor's Degree	16	44.4		8	44.4		8	44.4	
Master's Degree	10	27.8		8	44.4		2	11.1	
Doctoral Degree	4	11.1		0	0		4	22.2	
<i>Marital Status</i>									
Not Married or Partnered	9	25.0		6	33.3		3	16.7	
Married or Partnered	27	75.0		12	66.7		15	83.3	
<i>Employment Status</i>									
Currently Employed	23	63.9		13	72.2		10	55.6	
Not Currently Employed (Retired)	13	36.1		5	27.8		8	44.4	
Employment Hours Per Week	35		22.17 (20.71)	17		23.97 (19.04)	18		20.47 (22.59)
<i>Income</i>									
\$10,001 - \$50,000	7	19.4		3	16.7		4	22.2	
\$50,001 - \$100,000	7	19.4		4	22.2		3	16.7	
\$100,001 - \$150,000	6	16.7		2	11.1		4	22.2	
\$150,000+	12	33.3		8	44.4		4	22.2	
Prefer Not to Answer	4	11.1		1	5.6		3	16.7	
<i>Relationship to Care Recipient</i>									
Child	22	61.1		12	66.7		10	55.6	
Spouse/Partner	9	25		4	22.2		5	27.8	
Grandchild	3	8.3		1	5.6		2	11.1	
Friend	1	2.8		0	0		1	5.6	
Neighbor	1	2.8		1	5.6		0	0	

Note. This table describes all baseline demographic variables included in the current study, including characteristics of the total sample (N = 36) and each interview condition.

Appendix D

Table 2

Caregiver Health Characteristics

Baseline Characteristic	Full Sample N = 36			Hobby Interview N = 18			Caregiving Stress Interview N = 18		
	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)
<i>Health Characteristic</i>									
Self-Rated Health									
Excellent	15	41.7		7	39.8		8	44.4	
Good	19	52.8		10	55.6		9	50.0	
Fair	2	5.6		1	5.6		2	5.6	
High Blood Pressure (HBP) History									
Yes	11	30.6		6	33.3		5	27.8	
No	25	69.4		12	66.7		13	72.2	
Current HBP Medication									
Yes	11	30.6		6	33.3		5	27.8	
No	25	69.4		12	66.7		13	72.2	
Handedness									
Right	30	83.3		16	88.9		14	77.8	
Left	6	16.7		2	11.1		4	22.2	
Pulse	33		75.82 (12.68)	16		75.69 (9.48)	17		75.94 (15.04)
Blood Pressure									
Systolic	36		121.53 (19.88)	18		123.06 (20.32)	18		120.00 (19.89)
Diastolic	36		81.97 (10.06)	18		84.56 (11.58)	18		79.39 (7.76)

Note. This table describes all baseline health variables included in the current study, including characteristics of the total sample (N = 36) and each interview condition.

Appendix E

Table 3

Care Recipient Characteristics

Baseline Characteristic	Full Sample N = 36			Hobby Interview N = 18			Caregiving Stress Interview N = 18		
	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)
<i>Care Recipient</i>									
<i>Gender</i>									
Male	10	27.8		5	27.8		5	27.8	
Female	26	72.2		13	72.2		13	72.2	
Age	36		82.08 (8.96)	18		81.22 (8.59)	18		82.94 (9.50)
<i>Nature of Care Needs</i>									
Memory	5	13.9		1	5.6		4	22.2	
Psychological	2	5.6		1	5.6		1	5.6	
Physiological	10	27.8		7	38.9		3	16.7	
Age-Related	3	8.3		1	5.6		2	11.1	
Neurological	2	5.6		1	5.6		1	5.6	
Multiple Care Needs	14	38.9		7	38.9		7	38.9	

Note. This table describes all care recipient characteristics included in the current study, including those of the total sample (N = 36) and each interview condition.

Appendix F

Table 4

Caregiver Care Activities

Baseline Characteristic	Full Sample N = 36			Hobby Interview N = 18			Caregiving Stress Interview N = 18		
	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)	<i>n</i>	%	M (<i>SD</i>)
<i>Caregiving Activities</i>									
Primary Caregiver Status									
Yes	22	69.1		12	66.7		10	55.6	
No	14	38.9		6	33.3		8	44.4	
Average Hours Per Week Spent Caregiving	35		31.86 (49.15)	17		35.41 (53.03)	18		28.50 (46.48)
Duration of Current Caregiving (Months)	36		54.28 (75.94)	18		58.33 (101.63)	18		50.22 (38.85)
Previously a Caregiver									
Yes	25	69.4		12	66.7		13	72.2	
No	11	30.6		6	33.3		5	27.8	
Duration of Other Caregiving (Months)	34		41.47 (51.87)	17		32.26 (47.04)	17		50.68 (56.18)
Lifetime Duration of Caregiving (Months)	34		98.08 (63.85)	17		88.81 (105.94)	17		98.08 (63.85)

Note. This table describes all baseline care activity variables included in the current study,

including those of the total sample (N = 36) and each interview condition.

Appendix G

Table 5

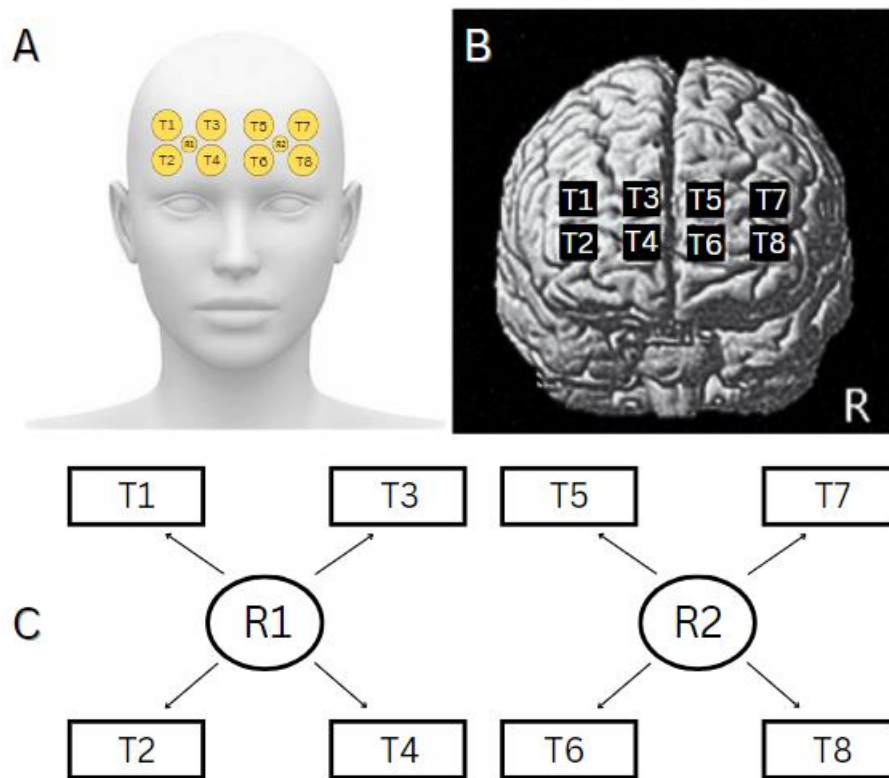
Baseline Scale Scores

Baseline Scale Measure	Full Sample N = 36		Hobby Interview N = 18		Caregiving Stress Interview N = 18	
	<i>n</i>	<i>M(SD)</i>	<i>n</i>	<i>M (SD)</i>	<i>N</i>	<i>M (SD)</i>
BADL	36	21.39 (12.20)	18	19.78 (12.26)	18	23.00 (12.28)
Self-Efficacy						
Obtaining Respite	36	68.07 (26.33)	18	67.32 (23.49)	18	68.83 (29.57)
Responding	36	78.04 (22.67)	18	78.28 (22.57)	18	77.80 (23.42)
Controlling Thoughts	36	75.54 (22.56)	18	79.10 (20.32)	18	71.97 (24.66)
Cognitive Failures Questionnaire						
Total Score	35	36.46 (13.39)	18	37.06 (12.51)	17	35.82 (14.63)
Forgetfulness	35	14.23 (4.86)	18	14.83 (4.97)	17	13.59 (4.84)
Distractibility	35	12.97 (5.18)	18	13.22 (5.33)	17	12.71 (5.17)
False Triggering	35	8.40 (4.39)	18	8.78 (4.26)	17	8.00 (4.62)
Stress-Arousal						
Stress	36	9.50 (3.65)	18	8.17 (3.59)	18	10.83 (3.29)
Arousal	36	14.36 (4.11)	18	13.33 (4.43)	18	15.39 (3.60)

Note. This table describes all baseline scale scores included in the current study, including those of the total sample (N = 36) and each interview condition.

Appendix H

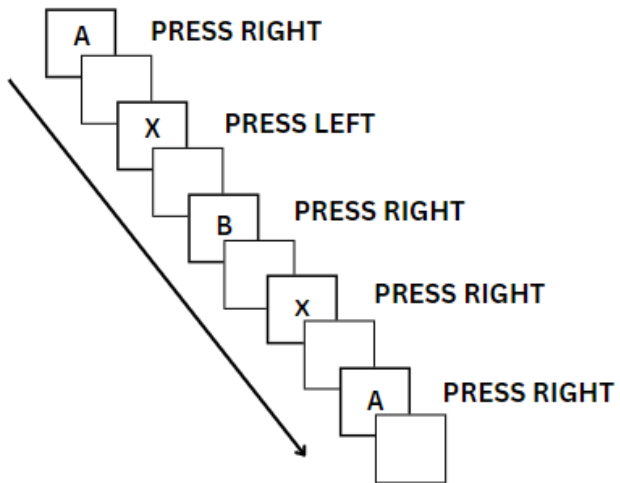
Figure 3

fNIRS Octamon Electrode Placement

Note. Placement of Octamon system's 8 channels and 2 detectors A) on human model, B) in diagram, and C) overlaid on cortical structure (adapted from Li et al., 2022). Channels are grouped to form Group 1 (G1) which consists of channels T1-T4 and Group 2 (G2) which consists of channels T5-T8. Total oxygenation, using all channels (T1-T8), is also calculated and used in subsequent analyses.

Appendix I

Figure 4

AX-CPT Task

Note. This figure depicts an example of AX-CPT trials and their correct responses.

Appendix J

Table 6

Caregiver Demographics X Outcome Variable Correlations

Variable	SAI – Stress (B)	SAI – Stress (PI)	SAI – Arousal (B)	SAI – Arousal (PI)	Accuracy (T)	Accuracy (AX)	Accuracy (AY)	Accuracy (BX)	Accuracy (BY)	RT (T)	RT (AX)	RT (AY)	RT (BX)	RT (BY)	Total O2HB (B)	G1 O2HB (B)	G2 O2HB (B)	Total O2HB (AX-CPT)	G1 O2HB (AX-CPT)	G2 O2HB (AX-CPT)
Age	.424**	.254	.249	.262	.002	-.016	.266	-.199	.062	.489**	.451**	.499**	.400*	.467**	.086	.075	.097	.444**	.421*	.459**
Gender	-.391*	-.313	-.187	.065	.335*	.291	.380*	.327	.443**	.249	.086	.206	.413*	.167	.088	.081	.095	-.092	-.058	-.124
Race	-.547**	-.065	-.228	-.241	-.107	-.094	-.200	.072	-.216	-.146	-.093	-.275	-.094	-.151	-.161	-.169	-.152	.223	.233	.210
Education	-.046	.177	.019	.030	-.089	-.121	-.018	.176	-.025	.015	-.028	.026	.066	.116	-.045	-.053	-.037	.122	.133	.111
Marital Status	.178	.137	-.062	.186	.044	.041	.082	-.018	.053	.113	.072	.121	.111	.090	-.073	-.074	-.070	.173	.182	.162
Employment Status	.067	.141	.072	.128	.192	.165	.236	.167	.275	-.125	-.178	-.067	-.099	-.046	-.189	-.176	-.203	-.168	-.137	-.195
Hours Worked Per Week	-.001	.235	.101	.132	.065	.007	.236	.282	.244	-.175	.007	-.128	.001	-.068	-.144	-.133	-.155	-.121	-.112	-.129
Income	-.107	-.128	.050	-.121	-.090	-.123	.053	.125	-.055	.025	.036	-.018	.136	-.023	-.032	-.040	-.023	.309	.267	.337*

Note. B = Baseline, PI = Post-Interview, T = Total, O2HB = Average Blood Oxygenation, * p < .05, ** p < .01

Appendix K

Table 7

Caregiver Health X Outcome Variable Correlations

Variable	SAI – Stress (B)	SAI – Stress (PI)	SAI – Arousal (B)	SAI – Arousal (PI)	Accurac y (T)	Accurac y (AX)	Accurac y (AY)	Accurac y (BX)	Accurac y (BY)	RT (T)	RT (AX)	RT (AY)	RT (BX)	RT (BY)	Total O2HB (B)	G1 O2HB (B)	G2 O2HB (B)	Total O2HB (AX- CPT)	G1 O2HB (AX- CPT)	G2 O2HB (AX- CPT)
Self-Rated Health	.191	.135	.389*	.190	-.188	-.222	.064	.014	-.183	.050	.059	-.005	.114	.098	-.085	-.081	-.089	.041	.053	.028
BP Systolic	.210	.154	.027	-.082	-.266	-.278	-.116	-.157	-.180	.040	.019	.045	.159	.046	.032	.024	.042	.262	.209	.310
BP Diastolic	-.139	-.006	-.028	.000	-.031	-.026	-.148	.050	-.012	-.219	-.220	-.212	-.109	-.236	-.056	-.065	-.046	.028	-.019	.073
Pulse Baseline	.088	.148	.107	.190	-.017	.020	-.122	-.223	-.063	-.064	.015	-.125	-.186	-.034	-.047	-.048	-.045	-.185	-.207	-.162
History HBP	.209	.196	-.126	-.172	-.127	-.120	-.042	-.314	.031	.166	.128	.274	.147	.210	-.090	-.091	-.090	.180	.155	.202
HBP Medication	.209	.196	-.126	-.172	-.127	-.120	-.042	-.314	.031	.166	.128	.274	.147	.210	-.090	-.091	-.090	.180	.155	.202
Handedness	.144	-.106	.228	-.042	-.300	-.279	-.227	-.290	-.349*	.063	.153	-.030	.045	.029	.401*	.404*	.397*	-.059	-.081	-.037

Note. B = Baseline, PI = Post-Interview, T = Total, O2HB = Blood Oxygenation, * $p < .05$, ** $p < .01$

Appendix L

Table 8

Care Recipient and Caregiving Activity X Outcome Variable Correlations

Variable	SAI – Stress (B)	SAI – Stress (PI)	SAI – Arousal (B)	SAI – Arousal (PI)	Accuracy (T)	Accuracy (AX)	Accuracy (AY)	Accuracy (BX)	Accuracy (BY)	RT (T)	RT (AX)	RT (AY)	RT (BX)	RT (BY)	Total O2HB (B)	G1 O2HB (B)	G2 O2HB (B)	Total O2HB (AX-CPT)	G1 O2HB (AX-CPT)	G2 O2HB (AX-CPT)
Relationship between CR and CG	-.159	-0.14	-.127	-.088	.053	.060	-.009	.050	.009	-.178	-.156	-.151	-.150	-.175	-.106	-.105	-.107	-.383*	-.371*	-.390*
CR Age	.224	.011	.248	.257	.194	.184	.231	.102	.151	.081	.075	-.016	.068	-.010	.422*	.426*	.417*	-.032	-.017	-.046
CR Gender	.071	-.050	-.121	-.121	.344*	.367*	.149	.105	.253	-.116	-.106	-.070	-.249	-.108	.123	.139	.105	.162	.170	.152
CR Care Need	-.203	-.071	-.069	-.026	-.096	-.091	-.038	-.104	-.129	.146	.148	.040	.187	.072	-.115	-.121	-.109	.064	.103	.024
Primary CG	.282	.070	.047	.135	.133	.112	.221	.088	.161	.115	.064	.206	.071	.163	-.209	-.196	-.224	.039	.061	.017
Average Hours Caregiving/Week	.246	.210	-.029	-.128	-.070	-.036	-.292	-.086	-.060	-.155	-.217	-.137	-.083	-.174	-.035	-.034	-.037	.071	.065	.076
Duration of Current Caregiving	.235	.112	.145	.099	.007	.041	.177	-.563**	.017	.495**	.606**	.498**	.173	.606**	.203	.205	.201	.098	.074	.120
Other Caregiving Activities	.104	-.074	.109	.079	.221	.193	.361*	.089	.264	.186	.104	.337*	.169	.131	-.313	-.310	-.316	.108	-.130	.086
Other Caregiving Activity Duration	.097	-.146	.010	.043	.087	.054	.213	.125	.154	.031	-.067	.098	.122	.030	-.189	-.185	-.193	-.065	-.017	-.109
Lifetime Caregiving Duration	.266	-.004	.115	.123	.046	.059	.259	-.432**	.103	.442**	.487**	.488**	.209	.542**	.089	.096	.081	.001	.001	.001

Note. B = Baseline, PI = Post-Interview, T = Total, O2HB = Blood Oxygenation, CG = Caregiver, CR = Care Recipient, * p < .05, ** p < .01

Appendix M

Table 9
Scale Score X Outcome Variable Correlations

Variable	SAI – Stress (B)	SAI – Stress (PI)	SAI – Arousal (B)	SAI – Arousal (PI)	Accuracy (T)	Accuracy (AX)	Accuracy (AY)	Accuracy (BX)	Accuracy (BY)	RT (T)	RT (AX)	RT (AY)	RT (BX)	RT (BY)	Total O2HB (B)	G1 O2HB (B)	G2 O2HB (B)	Total O2HB (AX-CPT)	G1 O2HB (AX-CPT)	G2 O2HB (AX-CPT)
BALDs	.152	.110	.192	.338*	-.100	-.100	-.081	-.038	-.087	-.279	-.327	-.399*	-.117	-.255	.018	.002	.035	-.073	-.077	-.068
SE: Obtaining Respite (M)	.068	.311	.334*	-.087	-.139	-.148	.030	-.143	-.122	.089	.096	.042	.135	.113	-.155	-.152	-.158	.132	.116	.147
SE: Controlling Thoughts (M)	.270	.487*	.246	.177	-.137	-.142	-.032	-.101	-.125	-.005	-.031	-.067	.072	.020	-.393*	-.398*	-.387*	.012	.011	.013
SE: Responding (M)	-.027	.366*	.176	.137	-.034	-.021	-.185	.047	-.025	-.325	-.320	-.316	-.254	-.287	-.432**	-.437**	-.426*	.018	.005	.031
Cognitive Failures Total Score	-.494**	-.219	-.446**	-.316	.093	.157	-.113	-.188	-.219	.048	.079	-.048	.036	.010	.146	.144	.148	-.197	-.218	-.173
CF: Forgetfulness	-.428*	-.240	-.419*	-.326	.183	.252	-.166	-.091	-.102	-.083	-.018	-.164	-.111	-.149	.022	.020	.024	-.194	-.223	-.164
CF: Distractibility	-.503**	-.228	-.407*	-.376*	.027	.118	-.225	-.238	-.216	.018	.060	-.047	-.043	-.002	.129	.133	.125	-.260	-.263	-.255
CF: False Triggering	-.397*	-.152	-.388*	-.128	-.003	.048	-.031	-.275	-.076	.173	.172	.091	.166	.157	.166	.165	.167	-.236	-.256	-.213

Note. B = Baseline, PI = Post-Interview, T = Total, O2HB = Blood Oxygenation, * p < .05, ** p < .01

Appendix N

Table 10

Outcome Variable X Outcome Variable Correlations

Variable	SAI – Stress (B)	SAI – Stress (PI)	SAI – Arousal (B)	SAI – Arousal (PI)	Accuracy (T)	Accuracy (AX)	Accuracy (AY)	Accuracy (BX)	Accuracy (BY)	RT (T)	RT (AX)	RT (AY)	RT (BX)	RT (BY)	Total O2HB (B)	G1 O2HB (B)	G2 O2HB (B)	Total O2HB (AX-CPT)	G1 O2HB (AX-CPT)	G2 O2HB (AX-CPT)
SAI – Stress (B)	-	.273	.453**	.149	-.224	-.232	.009	-.264	-.179	.082	.101	.105	.039	.155	.135	.145	.124	.137	.126	.146
SAI – Stress (PI)		-	.333*	.233	-.241	-.263	.032	-.187	-.169	.197	.199	.145	.237	.233	-.327	-.331	-.323	.133	.107	.156
SAI – Arousal (B)			-	.341*	-.259	-.276	.059	-.257	-.239	.231	.272	.107	.239	.244	.145	.141	.149	.094	.078	.108
SAI – Arousal (PI)				-	-.083	-.100	.073	-.062	-.042	.090	.147	-.005	.058	.088	.093	.081	.107	-.197	-.196	-.195
Accuracy (T)					-	.991**	.658**	.661**	.915**	-.002	-.123	.161	-.096	-.134	.039	.041	.036	.073	.086	.060
Accuracy (AX)						-	.575**	.598**	.869**	-.027	-.130	.131	-.163	-.165	.030	.033	.027	.059	.071	.046
Accuracy (AY)							-	.395*	.743*	.486**	.351*	.548**	.514**	.419*	.039	.037	.040	.151	.159	.142
Accuracy (BX)								-	.672**	-.418*	-.565**	-.268	-.236	-.492**	.093	.096	.089	.079	.092	.065
Accuracy (BY)									-	.073	-.116	.281	.088	.005	.039	.040	.038	.057	.066	.048
RT (T)										-	.955**	.928**	.881**	.947**	-.038	-.045	-.031	.136	.133	.137
RT (AX)											-	.847**	.813**	.960**	.002	-.003	.008	.116	.107	.122
RT (AY)												-	.794**	.882**	-.099	-.102	-.097	.175	.175	.174
RT (BX)													-	.837**	-.062	-.072	-.051	.080	.077	.081
RT (BY)														-	.021	.015	.027	.143	.134	.150
Total O2HB (B)															-	.999*	.999**	-.066	-.097	-.036
G1 O2HB (B)																-	.997**	-.070	-.099	-.040
G2 O2HB (B)																	-	-.062	-.094	-.031

Total O2HB (AXCPT)	-	.993**	.993**
G1 O2HB (AXCPT)	-		.971**
G2 O2HB (AXCPT)			-

Note. B = Baseline, PI = Post-Interview, T = Total, O2HB = Blood Oxygenation, * p < .05, ** p < .01

Appendix O

Table 11

AX-CPT Reaction and Accuracy Results (Adjusted Model)

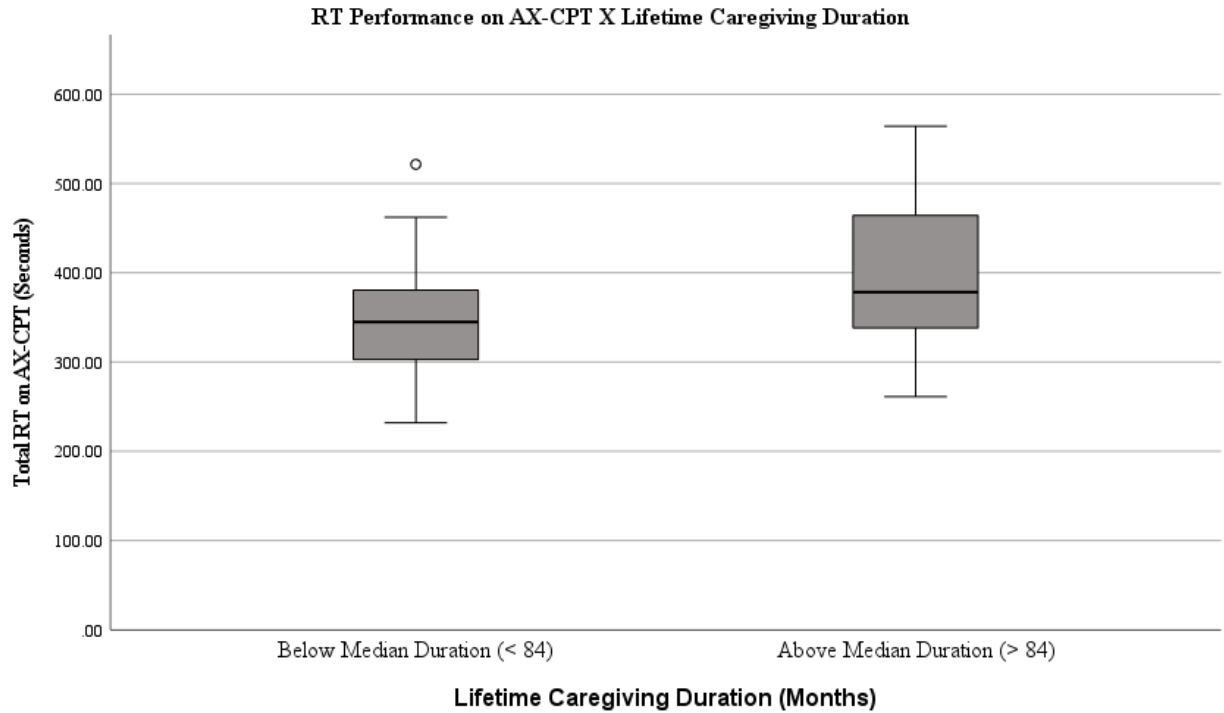
Measure	Caregiving Interview		Hobby Interview		<i>F</i> (1, 27)	p	Partial η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Reaction Time							
<i>Total</i>	391.74	17.47	362.37	17.47	1.356	0.254	0.048
AX	361.82	17.19	334.95	16.67	1.189	0.285	0.044
AY	413.96	17.80	398.04	17.27	0.389	0.538	0.015
BX	404.89	24.85	353.49	24.11	2.082	0.161	0.074
BY	377.05	18.93	356.65	18.36	0.565	0.459	0.021
Accuracy							
<i>Total</i>	88.26	3.38	94.86	3.38	1.826	0.188	.063
AX	87.43	3.99	96.30	3.99	2.374	0.135	0.081
AY	41.14	1.54	40.25	1.54	0.159	0.693	0.006
BX	43.14	1.19	44.47	1.19	0.592	0.592	0.021
BY	45.62	1.05	47.05	1.05	0.892	0.892	0.032

Note. This table describes the results of AX-CPT accuracy and reaction time x caregiving interview results.

Appendix P

Figure 5

RT Performance on AX-CPT X Lifetime Caregiving Duration



Note. This figure depicts significant differences in RT performance using a median split of the lifetime caregiving duration variable. One outlier is present in the data, as depicted by the hollow circle in the figure.

Appendix Q

Table 12

*f*NIRS Oxygenation Results (Adjusted Model)

Sources	Sum of Squares	df	MNSQ	F	p	Partial η^2 p
Total Oxygenation						
<i>Within-Subjects Effects</i>						
Oxygenation	469.211	1	469.211	4.767	0.039*	0.160
Oxygenation*Interview	74.799	1	74.799	0.760	0.392	0.029
Oxygenation*Duration	27.955	1	27.955	0.284	0.599	0.011
Residual	2460.794	25	98.432			
<i>Between Subjects Effect</i>						
Interview	178.463	1	178.463	1.976	0.172	0.073
Duration	27.606	1	27.606	0.306	0.585	0.012
Residual	2258.081	25	90.323			
G1 Oxygenation						
<i>Within-Subjects Effects</i>						
Oxygenation	423.010	1	423.010	4.032	0.056*	0.139
Oxygenation*Interview	82.562	1	82.562	0.787	0.384	0.031
Oxygenation*Duration	18.451	1	18.451	0.176	0.679	0.007
Residual	2623.145	25	104.926			
<i>Between Subjects Effect</i>						
Interview	195.210	1	195.210	2.134	0.157	0.079
Duration	20.199	1	20.199	0.221	0.643	0.009
Residual	2287.350	25	91.494			
G2 Oxygenation						
<i>Within-Subjects Effects</i>						
Oxygenation	517.806	1	517.806	5.466	0.028*	0.179
Oxygenation*Interview	67.418	1	67.418	0.712	0.407	0.028
Oxygenation*Duration	39.427	1	39.427	0.416	0.525	0.016
Residual	2368.144	25	94.726			
<i>Between Subjects Effect</i>						
Interview	162.466	1	162.466	1.766	0.196	0.066
Duration	36.169	1	36.169	0.393	0.536	0.015
Residual	2300.147	25	92.006			

Note. *.05