THE EFFECTS OF ACUTE PSYCHOSOCIAL STRESS ON EXECUTIVE FUNCTIONING IN YOUNG AND OLDER ADULTS

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Abstract

The Effects of Acute Psychosocial Stress on Executive Functioning in Young and Older Adults

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It has been evidenced that, with aging, older adults exhibit increased behavioral and physiological responses to stress. Older adults also often experience declines in executive functioning performance. The acute psychological stress induced through the Trier Social Stress Test (TSST) has been evidenced to negatively impact executive functioning in young adults. This relationship, however, has yet to be examined in older adults. In the current thesis, two experiments were conducted to investigate the effects of stress on executive functioning (Experiment 1), as well as age related differences in stress responsivity and in the effect of stress on executive functioning (Experiment 2). In Experiment 1, acute stress exhibited a negative effect on executive functioning. In Experiment 2, there were no age differences in stress responses, and a *positive* effect of acute stress on executive functioning in young adults only. The contradictory findings encourage further research on the effects of stress on executive functioning, and how they may differ between young and older adults.

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The Effects of Acute Psychosocial Stress on Executive Functioning in Young and Older Adults

Chapter 1. Introduction

Experiencing stress and exercising the mind are two distinct pillars that become repeatedly intertwined in our everyday lives. We constantly experience temporary or chronic stressors, which result in changes in human physiology, cognition, and behaviour (e.g., Lupien, McEwen, Gunnar, & Heim, 2009). Despite the comprehensive body of literature that investigates the effects of stress on cognition, it remains unclear how this relationship differs across different age groups (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004a). The current thesis aimed to investigate the relationship between acute psychosocial stress and executive functioning in older adults, age differences in stress responsivity, and age differences in the effects of acute psychosocial stress on executive functioning.

The following literature review section will begin with an overview of acute psychosocial stress induction, stress responsivity, and age-related differences in stress. It will be followed by a review of age-related changes in executive functioning, and the relationship between stress and executive functioning in young and older adults.

Stress and the Underlying Mechanisms

Research on the notion of stress dates back to an era before the term itself was coined. Walter Cannon initially coined the term "fight or flight", which describes the body's reaction to a stressor in terms of increasing the blood supply travelling to the brain and skeletal muscles, preparing the body to either fight the stressor or flee from it (Cannon, 1914, as cited in Sorrells & Sapolsky, 2007). The term 'Stress' was first coined in 1959 by Hans Selye as 'a state manifested by a specific syndrome which consists of all the non-specifically induced changes in a biologic system' (Selye, 1959, p.403).

Selye's pioneering work developed the foundation for stress research today. However, it disregarded some important elements of stress research. In addition to the biological mechanisms, stress is accompanied by emotional (Mason, 1971, as cited in Krohne, 2002) and cognitive (Lazarus & Folkman, 1986) components. The emotional components (unpredictability, novelty, threat to ego, and low sense of control; Lupien, 2009), are necessary for the initiation of a stress response. The lack of an emotional component in the context of a stressor may eliminate the generation of a stress response (Krohne, 2002). As for the cognitive component, it has been argued that a cognitive transformation of events is a required mediator in the stimuli-response relationship (Lazarus, 1966 as cited in Krohne, 2002). In this relationship, stress is defined by the significance one attributes to the stressor, as well as by the resources one appraises to have available in their environment (Lazarus et al., 1986). Stress could be experienced regarding specific life events (e.g., death of a loved one, loss of income), and it can also be experienced in milder forms on a daily basis, such as meeting a new colleague, or being late to an appointment. Regardless of the form of the stressor, it can have both an instant and a long-term effect on our physical and psychological health (Almeida, 2005).

Under the broad umbrella of stress, there are two main branches: *acute stress* and *chronic stress.* Acute stress arises from exposure to a stressor that remains for a short period of time, the onset of which is usually sudden, and the reaction is almost immediately manifested (Anshel, Robertson & Caputi, 1997). The reaction to acute stress changes depending on the intensity level of the stressor (Dhabhar & McEwen, 1997). Chronic stress occurs when a stressor endures for an extended period of time, such as when caring for a loved one who is ill. It could also be manifested when the stressor itself is temporary, but the feeling of stress remains for a long period of time. Stress, specifically acute stress, is essential for survival; it allows the individual to

adapt to the surrounding environment. However, extreme levels of stress can lead to hormonal dysregulation in the body, which is no longer adaptive, but rather harmful to the individual (Chrousos, 1998).

The physiological adaptation to stress that occurs within the body is modulated by the Sympathetic Adrenal Medullary (SAM) system and the Hypothalamic-Pituitary-Adrenal (HPA) axis, both of which are activated via stimulation of the hypothalamus. In the SAM system, sympathetic preganglionic fibres send signals via the neurotransmitter acetylcholine to the adrenal medulla (Tsigos & Chrousos, 2002). This results in the release of adrenaline from the adrenal medulla into the blood stream, which pushes oxygenated blood towards the heart, brain and muscles necessary to initiate a successful fight or flight response (Siegel & Sapru, 2006).

The HPA axis is one of the major neuroendocrine systems in the mammalian body (Del Rey, Chrousos & Besedovsky, 2008). It consists of a hormonal communication between the hypothalamus, the pituitary gland, and the adrenal gland. The HPA axis connects the central nervous system with the endocrine system (Tsigos & Chrousos, 2002). Once the body registers a stressor, the hypothalamus releases Corticotropin releasing hormone (CRH), which then binds to receptors on the pituitary gland, resulting in the release of the adrenocorticotropic hormone (ACTH). The ACTH in turn binds to receptors on the adrenal cortex, releasing glucocorticoids, or cortisol in humans. When cortisol is released, it pushes the available glucose in the body into the blood stream, so it can be circulated to the brain and skeletal muscles, providing them with energy to facilitate the fight or flight response (Tsigos & Chrousos, 2002). In order to provide more glucose to the blood stream, cortisol suppresses organ systems, such as the immune system, which have a reserve of glucose (Del Rey et al., 2008). Cortisol release occurs for up to several hours after the stimulus is removed (Tsigos & Chrousos, 2002). Cortisol then generates a

negative feedback loop where it travels to the hypothalamus and pituitary glands, binding with glucocorticoid receptors, hence stopping the production of CRH and ACTH, and returning the body's functioning to baseline (Tsigos & Chrousos, 2002). Collaboratively, the SAM system functions to provide oxygen, whereas the HPA-axis functions to release glucose, into the blood stream towards the brain and skeletal muscles, to prepare the body for a stress response.

Acute stress induction: The Trier Social Stress Test.

In order to empirically assess the impact of an acute stressor on the body, it must be induced and examined within a controlled lab setting. One of the most widely used tactics of stress induction in a controlled setting is the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). During the TSST, participants are provided with five minutes to prepare a speech on a predetermined topic (an anticipatory phase), they are then to deliver a speech on the assigned topic to two rigid confederates. The speech is followed by a complicated arithmetic task, which is to be verbally solved to the confederates (Kirschbaum et al., 1993). The TSST has shown considerable increases in stress levels over time, by increasing HPA axis activity, negative mood, and negative affect (McRae et al., 2006). The TSST is expected to have a greater effect later in the day as opposed to early in the morning. Cortisol levels are elevated in the morning hours, regardless of experiencing a stressor. Hence, the high levels of cortisol at baseline may result in a ceiling effect which would prevent any further increase of cortisol secretion upon the experience of a stressor (Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004).

Regarding the generalizability of the TSST effect across age and genders, Kudielka et al. (2004a) conducted a re-analysis of five studies that investigated the effect of TSST between males and females, across three different age groups (children, young and older adults). Increases in plasma cortisol levels indicated acute stress played a significant role in increasing the stress

levels across both genders and all age groups ($p < .001$; Kudielka et al., 2004a). Given its robustness, the TSST was adopted as a stress induction procedure in the current thesis project.

Age differences in stress responsivity.

A widely researched behavioural response that highlights age differences in stress responses is the kindling effect (Mroczek & Almeida, 2004). The kindling effect refers to increased sensitization due to repeated exposure to certain stimuli (Gilbert, 1994; Kendler, Thornton, & Gardner, 2001). The amygdala and the limbic system—the brain regions which manipulate negative affect—are impacted by repeated activation over the lifetime (Adamec, 1990; Panksepp & Miller., 1996). With age, these areas become more sensitized, influencing one's experience of negative events (Adamec, 1990; Panksepp et al., 1996). These sensitizations could result in an easier activation of negative affect when the individual experiences stressors in older age (Mroczek et al., 2004). Following this rationale, older adults would be more detrimentally impacted by stress compared to young adults.

Mroczek et al. (2004) investigated age differences in the Kindling effect via the National Study of Daily Events (NSDE), a daily diary study that spans eight consecutive days (Almeida, MacDonald, & Wethington 2001). Participants responded to phone interviews every night of the eight-day period. Interviews consisted of questionnaires that assessed daily negative affect, anxiety, depression, and appraisals such as hopelessness (Kessler et al., 2002). Additionally, daily stress was assessed via the semi-structured Daily Inventory of Stressful Events (DISE), which includes inquiries about stressors that occurred in the previous 24 hours (Almeida, et al., 2002). The data revealed that young adults reported more daily stressors and daily negative affect than older adults generally (Mroczek et al., 2004). However, older adults displayed a greater expression of negative affect as well as a more rigorous behavioural reaction *when*

exposed to stressors compared to young adults (Mroczek et al., 2004), supporting the kindling effect hypothesis. The mentioned literature on the kindling effect leads to the expectation that older adults will experience greater stress responsivity compared to young adults.

The age-related behavioural differences in stress responses are mirrored in the physiological changes that occur with aging. Research suggests that, when exposed to acute stress, older adults exhibit a greater increase in cortisol levels compared to young adults, this is especially true among older females (Kudielka et al., 2004a). The age differences in cortisol release can be partially explained by allostatic load (McEwen & Stellar, 1993). Allostatic load is the wear and tear experienced when repeated allostatic responses are activated during stressful situations (McEwen & Stellar, 1993). It is when allostasis, the method in which the body's biomarkers fluctuate to meet environmental demands, becomes over-burdened (McEwen, 1998). These biomarkers include blood pressure, cholesterol, and cortisol. With repeated exposure to emotionally charged life events, maladaptive diet and exercise, and stressful life events, the human body develops greater allostatic load. Some research has evidenced an increase in allostatic load with age from young to older adulthood (e.g., Crimmins, Johnston, Hayward, & Seeman, 2003). This might explain why the circulating cortisol levels at rest are higher in an older adult's body than a young one's (Vgontzas et al., 2003). It should be noted that other research confirmed that allostatic load does not correlate with age. An adult with unhealthy lifestyle habits who faces many life stressors would potentially have a greater allostatic load than a person with a healthier, less stressful lifestyle, regardless of age. Furthermore, allostatic load has been shown to decrease in older age, and increase longevity (Karlamangla, Singer, & Seeman, 2006). Age is only one of many factors, such as socio-economic status or hostility, which contribute to higher allostatic load (Kubzansky, Kawachi, & Sparrow, 1999).

As mentioned earlier, after the exposure to an acute stressor subsides, the HPA axis creates a negative feedback loop that inhibits the production of cortisol. With age, the hypothalamus and pituitary gland become desensitized to the negative feedback loop, hence the production of CRH and ACTH becomes less inhibited, leading to generally higher levels of cortisol in the older adult's body (McEwen, 1988). These findings suggest that not only do older adults maintain higher levels of cortisol at rest, but once exposed to an acute stressor, the increased level of cortisol remains high for a longer period of time compared to that of a young adult.

Due to the observed notions of the kindling effect and the increase in cortisol levels in older age, it is expected that older adults will be more detrimentally affected by acute stress exposure compared to young adults.

Executive Functioning

Executive functions refer to a set of high-order cognitive functions that are critical in planning, emotion regulation (Hendrawan et al, 2012), memory (Fisk & Sharp, 2004), and coordinating other lower-order cognitive functions (Miyake et al, 2000; Salthouse, Atkinson, & Berish, 2003). Executive functions encompass four constructs: updating, shifting, inhibition, and access (Fisk & Sharp, 2004). Updating refers to a modification of, or addition to, the store of information in working memory (Diamond, 2013). Shifting refers to the ability to alternate tasks, such as converting one's cognitive resources from one stimulus to another or switching responses from one dimension to another. Inhibition refers to the ability to restrict the processing of distracting information when attending to important target information. Finally, access refers to the brain's ability to retrieve stored information from long-term memory (Fisk & Sharp, 2004).

Brain mechanisms of executive functions

Executive functions are primarily managed via the frontal cortex (Alvarez & Emory, 2006). Specific aspects of executive functioning are managed by different regions of the frontal cortex. For example, the control of behavioural and social functions is carried out in the *orbitofrontal cortex* (Lezak, 2004), whereas aspects that involve working memory, such as planning, and problem solving occur in the *dorsolateral prefrontal cortex* (Alvarez & Emory, 2006). Although executive function control occurs mostly in the frontal cortical regions of the brain, it should be noted that non-frontal regions of the brain are also involved (Alvarez & Emory, 2006).

Executive functions work collaboratively with both working memory and attention. For example, the updating and shifting components of executive functioning are imperative to the functioning of working memory (Hull, Martin, Beier, Lane, & Hamilton, 2008). Moreover, the inhibitory component of executive functioning is an important aspect of attention, as it allows individuals to inhibit distracting information and attend to the task at hand (Kramer, Humphrey, Larish, & Logan, 1994). Responses on executive functioning and working memory tests have been found to be highly correlated, as they have underlying commonalities that are predictive of higher-level cognition (McCabe et al., 2010). Furthermore, executive functioning, memory, and attention overlap in the use of the same brain structures, such as the thalamus (Van der Werf et al., 2003). This demonstrates that executive functioning is importantly related to many cognitive functions, including attention and working memory. In the current project, executive functioning was assessed with commonly used measures rely heavily on working memory and attention (N-Back and Stroop).

Executive functioning and aging

The cognitive aging literature robustly depicts significant decreases in executive functioning with age (e.g., Salthouse & Babcock, 1991; Kim, & Giovanello, 2011; Kray & Lindenberger, 2000). One explanation of such age-related changes is the *dedifferentiation hypothesis* (Balinsky, 1941), which states that executive functioning constructs become meshed together in older age, leading to reduced executive functioning ability. This hypothesis has not been fully supported as the empirical evidence has been mixed (Hull et al., 2008). Regardless, the literature has repeatedly shown that, in older age, there is a consistent decline in various cognitive functions, including but not limited to executive functions (Dahlin, Nyberg, Backman & Neely, 2008; Braver et al., 2001). One such executive function is inhibitory control. The decline in inhibitory control results in older adults' increased attention towards irrelevant information in the environment, which in turn depletes their cognitive resources to attend to relevant information, leading to poorer attentive performance (Hasher & Zacks, 1988). Recent research has demonstrated that the multiple types of inhibition have independent neural mechanisms; age related declines may occur in some aspects of inhibitory control, but not in others (Anguera & Gazzaley, 2012).

In addition to the literature on inhibition, other components of executive functioning have been investigated across different age groups. The shifting component of executive functioning dwindles in older age, as older adults are not as able to diverge their attention from one topic to another as quickly or as easily as young adults are (Kray & Lindenberger, 2000). Age related declines also occur in the updating component of executive functioning, assessed using cognitive tasks such as the reading span, computation span, and consonant updating task (Fisk & Sharp, 2004). Not all aspects of executive functioning decline at the same rate. Access, for example, remains intact through old age (Fisk et al., 2004), which explains how some aspects of cognition,

such as verbal knowledge, are maintained in late life (Park et al., 2002). The three other constructs of executive functioning —inhibition, shifting and updating—however, decline significantly in older age (Fisk et al., 2004).

The literature on executive functioning and aging suggests that individuals in late life experience executive functioning deficits. However, little is known on whether age-related changes in executive functioning compromise executive faculties when exposed to acute psychosocial stress.

Stress and Executive Functioning

Stress impacts cognitive functioning negatively (Stawski, Sliwinski, & Smyth, 2006; Sliwinski, Smyth, Hofer, & Stawski, 2006). An example of this relationship is demonstrated in Stawski et al.'s (2006) study, where older adult participants underwent a battery of cognitive tests, as well as stress and mood assessment scales. The researchers correlated participants' cognitive task scores with their scores on the mood and affect scales. Results showed that those who reported higher levels of stress performed more poorly on cognitive tasks. Thus, it was inferred that stress diminishes attentional resources, resulting in poorer performance in working memory, episodic memory, and processing speeds (Stawski et al., 2006). The evidence suggests that stress may impact on executive functioning negatively in older age.

The interplay between stress physiology and cognition

Some of the physiological explanations of the effects of stress on executive functioning are based on the cognitive effects of cortisol. Cortisol crosses the blood brain barrier, modulating the functioning of the hippocampus and the prefrontal cortex (Schacter & Tulving, 1994; Braver et al., 2001). Other impacts of cortisol include an imbalance in the cognitive and emotional circuits in the brain and nervous system (Chrousos, 1998; Het et al., 2005). Furthermore, it has

been evidenced that exposure to high levels of glucocorticoids is correlated with a reduced hippocampus and memory impairments (Ling, Perry, Tsuang, 1981; Starkman, Gebarski, Berent, Schteingart, 1992). The effects of stress on the hippocampus, and thus memory, have been well established over the years (e.g., Kim & Yoon, 1998). The effects of stress on the prefrontal cortex, however, have only recently been discovered, and thus have not been empirically examined yet. Inferring from the relationship between memory and executive functioning (McCabe et al., 2010), it can be speculated that cortisol will have a similarly detrimental effect on executive functioning.

Some evidence suggests an inverse relationship, such that cortisol benefits cognitive functioning. Such conflicting results can be described by the Yerkes–Dodson law, which states that arousal—to some extent—is beneficial for performance, but an excessive amount of arousal would impact performance negatively (Yerkes & Dodson, 1908). Cortisol secreted in small amounts might enhance executive functioning, but excessive amounts of stress or cortisol release might impact executive functioning negatively.

Age differences in the impact of stress on executive functioning

Several studies have characterized the negative impact of stress on executive functioning among young adults (e.g. Schoofs, Preuss & Wolf, 2008; Bar-Tal, Raviv & Spitzer, 1999). For example, Palmer (2013) examined sixty college students who completed a battery of tests that assessed their stress levels, as well as their neurocognitive and executive functioning abilities. Results showed that young adults who experience more stress, and thus release more cortisol, obtain lower scores on working memory tasks (Palmer, 2013). Thus, it can be inferred that stress is negatively correlated with executive functioning among young adults.

It has also been evidenced that older adults experience worsened cognitive performance generally when exposed to stress (e.g., Mroczek and Almeida, 2004). Acute stress has resulted in worsened performance in memory and attention tasks in older adults (Lupien et al., 1997). Considering that memory and executive functioning are interrelated (McCabe et al., 2010), it has been postulated that stress might also negatively impact executive functioning in older adults (Lupien et al., 1997). Furthermore, the notion that older adults can be more sensitive to the effects of cortisol compared to young adults (Seeman, McEwen, Singer, Albert, & Rowe, 1997) combined with the age-related changes that occur in the anterior pre-frontal cortex (Schacter, Savage, Alpert, Rauch, & Albert, 1996), leads to the prediction that stress will have a more detrimental impact on executive functioning in older adults compared to young adults. Little research has directly examined the effects of acute psychosocial stress on executive functioning, specifically in older adults, or how the relationship differs between young and older adults. The current thesis aimed to fill these gaps.

The Current Thesis

Acute stress increases behavioural and physiological stress levels (McRae et al., 2006). Acute stress has a negative effect on cognitive functioning, for both young and older adults (Stawski et al., 2006; Mroczek et al., 2004). Specifically, the literature regarding young adults depicts detrimental effects of acute stress on executive functioning (Schoofs et al., 2008). However, this relationship has yet to be investigated among older adults, and the effects of acute stress on executive functioning in young and older adults have not been compared.

To address these gaps in the literature, two experiments were conducted. Experiment 1 examined whether exposure to acute stress would have a negative effect on executive functioning in older adults, as measured by an updating task (N-back; Kirchner, 1958), and an

inhibition task (Stroop; Stroop, 1935). It was hypothesized that, compared with a non-stress control condition, acute stress would result in lower performance on tasks of executive function. Experiment 2 examined age differences in stress reactivity and the impact of acute stress on executive functioning between young and older adults. It was hypothesized that older adults would exhibit greater reactivity to acute stress compared to young adults, as evidenced by higher cortisol secretion following acute stress. It was also hypothesized that acute stress would have a more detrimental impact on executive functioning in older adults compared to young adults.

Chapter 2. General Method

Measures and Materials

The same measures and materials were used in Experiments 1 and 2, unless stated otherwise.

Psychological questionnaires.

Participants completed questionnaires that measure mood and perceived stress at baseline and in response to the stress induction protocol.

Baseline questionnaires.

Perceived Stress Scale (PSS). The perceived stress scale is a 10-item questionnaire which assesses one's perceived stress level over the previous month (Cohen, Kamarck, & Mermelstein, 1983). Each question on the scale is answered by a five-point likert scale, where participants can circle a rating from a score of zero (never), to four (very often). Four of the questions are reverse coded. The PSS has been shown to produce valid and reliable results in both young and older adults (e.g., Ezzati et al., 2014), with a cronbach's alpha that has been shown to vary between .73 and .91 (Lee, 2012). This measure was administered at baseline to provide an estimate of general stress among participants.

The Depression, Anxiety and Stress Scale (DASS-21). The DASS-21 is a 21-item questionnaire which is divided in three sets of seven items that assess each of the factors: depression, anxiety and stress over the previous week (Lovibond et al., 1995). Each statement is associated with a 4 item likert scale that ranges from zero (the item does not apply to them at all) to three (the item applies to them very much). The DASS-21 has been shown to produce valid (Henry & Crawford, 2005) and reliable results in both young and older adults (range of alphas:

.80-.91; Sinclair et al., 2012). This measure was administered at baseline to provide an estimate of mood among participants.

Stress-induction questionnaires.

The Self –Reported Stress Scale (SRSS). This is a lab-created scale, where participants are instructed to rate their level of stress *at the current moment* on a scale of 1 (lowest level of stress) to 10 (highest level of stress). This measure was administered at three time points (pre-TSST, immediately post-TSST, and 35 min post-TSST) to provide an index of self-reported stress in response to the psychosocial stressor.

The Positive and Negative Affect Scale (PANAS). The PANAS is a 20-item scale. Ten items assess positive affect, and ten assess negative affect (Watson, Clark, & Tellegen, 1988). Participants rate these items, based on their feelings and emotions *at the current moment,* using a five-point likert scale which ranges from a score of one (not at all) to five (extremely). The PANAS is a well-established scale that has been shown to produce valid and reliable results in both young and older adults (range of alphas: .80-.91; Crawford & Henry, 2004). This measure was administered at three time points (pre-TSST, immediately post-TSST, and 35 min post-TSST) to assess affect in response to the TSST.

Cognitive measures.

Participants completed a set of cognitive tasks at baseline and following the stress induction protocol.

Baseline cognitive measures.

The Digit Symbol Substitution Test (DSST). The DSST is a processing speed task, where participants are required to match certain symbols to corresponding digits as quickly as possible with a two-minute time limit (Wechsler, 2014). It has been shown to produce reliable results in

both young and older adults, on the condition that practice effects are controlled for (Hinton-Bayre & Geffen, 2005). This measure was administered at baseline to provide an estimate of general cognitive functioning.

The Digit Span Task (DS). The DS task assesses working memory, participants are required to repeat sets of digits verbally stated by the researcher in the same order (forward), and in the opposite order (backward; Wechsler, 2014). This measure was administered at baseline to provide an estimate of general cognitive functioning.

The Mini-Mental State Examination (MMSE). The MMSE is a 30 item questionnaire used to screen for dementia (Folstein, Folstein, & McHugh, 1975). The examiner verbally asks the participant questions that assess orientation to time and space, arithmetic ability, recall and language, among others. The MMSE has been shown to produce valid and reliable results in older adults (range of alphas: .45 and 50; Mitrushina & Satz, 1991). This measure was administered at baseline to provide an estimate of general cognitive functioning among participants.

Post-stress executive functioning tasks.

Participants underwent two executive functioning tasks (i.e., N-back and Stroop) following the stress/control condition. Both tasks require continuous maintenance of task goals in the presence of competing or distracting non-target information. Executive functioning was indexed with the following dependent variables: accuracy, reaction time (RT), and response interference. In experiment 1, the order of the two executive functioning tasks was fixed, where the Stroop task was administered first, followed by the N-back task. In experiment 2, the order of the two executive functioning tasks was counterbalanced across participants, where half of the

participants in each group completed the N-back task first and the other half completed the Stroop task first.

N-back task. The N-back task primarily measures updating. In this task, participants were presented with individual letters sequentially presented at the center of a computer screen, each followed by a fixation point that signals participants to respond. There were two blocks: a 1-back task followed by a 3-back task block. In the 1-back task, participants were required to respond by pressing the green key labelled 'Target' if the letter was identical to the one presented immediately before it, and press the red key labelled 'Non-Target' if it was *not* identical to the one presented immediately before it. In the 3-back task, participants responded by pressing the 'Target' key if the letter presented was identical to the one presented three letters before it, and otherwise respond by pressing the 'Non-Target' key. The dependent variables were RT and accuracy. The N-Back task has been shown to produce valid and reliable results in some, but not all, aspects of working memory (Jaeggi, Buschkuehl, Perrig, & Meier, 2010; Kane, Conway, Miura, & Colflesh, 2007).

Stroop Task. The Stroop task measures inhibition. The task began with a test-familiarization (neutral) session, where a series of X strings (e.g., XXXX) were presented on the screen in one of four colours: blue, yellow, purple and brown. Participants were to respond to the ink color by pressing the corresponding colour labelled keys on the keypad. In the actual task, a series of X strings or colour word were presented in one of four colours. Participants were required to respond to the ink colour while ignoring the meaning of the colour words. There were three types of trials: neutral (e.g., "XXXX" printed in blue ink, should be responded as BLUE), congruent (e.g., "BLUE" printed in blue ink, should be responded as BLUE), and incongruent trials (e.g., "BLUE" printed in yellow ink, should be responded as YELLOW). Dependent

variables included accuracy, RT, and the Stroop interference ratio score in accuracy and RT (i.e., difference between incongruent and neutral condition divided by neutral condition performance).

Stress induction and control tasks.

The Trier Social Stress Test (TSST). The TSST was used to induce an acute stress response (see Kirschbaum et al., 1993). The pre-determined speech topic for both experiments included: insurance companies for young adults and social media for older adults. Once presented with the topic, participants were given five minutes to prepare a speech on the topic (anticipation phase). Once the anticipation phase was complete, participants were asked to deliver a five-minute speech to two confederates on the assigned topic, while falsely informed that they were being both video and audio recorded. Both confederates dressed in white lab coats and carried an intimidating demeanor. The participants were instructed to present for the full time allotted. If they finished speaking early, the confederates watched them silently for the remainder of the speech phase. After the presentation task, the participants were given an arithmetic task, where they were instructed to subtract the number 17 from 2023, out loud, then keep subtracting the number 17 from each answer until the confederates asked them to stop. If the participants provided an incorrect response or took too long to provide an answer, they were instructed to start over, beginning with the number 2023. This session was held for five minutes. Once the arithmetic task was complete, the confederates left the room, the audio and video recorders were removed, and the participants were asked to return to their seat, marking the end of the TSST session.

Control Condition. Experiment 1: Participants were escorted to a waiting room where they were told to "take a break and relax". They were provided with entertainment magazines for distraction. Any controversial materials or distressing news were removed from the magazines

beforehand. The waiting session was held for 15 minutes. Experiment 2: The control group underwent a friendly conversation task, where participants were allowed five minutes to write down or think about topics that they found interesting to discuss. The participant and researcher then had a friendly conversation about these topics for five minutes. After the conversation period was complete, participants were given an arithmetic task where they subtracted the number two from 200, out loud, and then kept subtracting the number 2 from each answer for five minutes. The participants were not interrupted or corrected for any miscalculations during the session.

Stress Reaction Measures.

Cortisol Assays. Salivary cortisol samples were collected throughout the stress induction protocol (and control condition) with Salimetrics (LLC) swabs and collection vials, and stored in a -70 degree Celsius fridge in the Cortisol Assays Lab located within the Harry Rosen Institute. Cortisol assays were conducted in the Assay Lab. The assay kits were also provided by Salimetrics LLC. The assays were conducted using competitive ELISA kits (e.g., Haussmann, Vleck, & Farrar, 2007). All materials were brought to room temperature prior to the conduction of the assay. All samples were vortexed and centrifuged, this was to extract as much saliva as possible from the swabs used to collect it, and to allow it to pool at the bottom of the vial. After the centrifuge procedure was successful, the swabs were removed from the vials, leaving only liquid saliva. Each sample was pipetted in 25 μl duplicates, into separate wells of the assay plate. 200 μl of the assay diluent was then added to each well, the plate was mixed on a plate rotator at 500 rpm for 5 minutes, and then left to incubate for 55 minutes. During the incubation period, cortisol binds to the receptors on the plate wells.

Once the incubation period was complete, the liquid contents of the plate were disposed of by flipping the assay plate over vertically, and then washing the plate repeatedly with a wash buffer, while avoiding cross contamination between wells. This process leaves only the cortisol that has bound to the surface of the wells in the assay plate. A tetramethylbenzidine (TMB) substrate was then pipetted in 200 μl increments into each well. Any available cortisol reacted to the substrate, producing a blue colour in the solution. The plate was then mixed in a plate rotator at 500 rpm for five minutes, and placed to incubate in a dark environment for 25 minutes. Finally, a stop solution was pipetted in 50 μl increment in each well, to stop any remaining chemical reactivity in the wells, turning the solution into the colour yellow. The plate was once again mixed on a plate rotator at 500 rpm, for three minutes. The data was inserted in the Gen5™ software, which reads the optical density of the plate, and produces cortisol levels in μg/dL per well (Biotek, Winooski, VT).

Competitive Elisa's have been shown to assess cortisol concentrations in a reliable and valid fashion (Cooper et al., Trunkfield, Zanella, & Booth, 1989). Any researcher-based errors in the assay were calculated via the inter (across plates) and intra (across sample duplicates) assay coefficients of reliability. The inter-assay reliability is calculated via the coefficient of variation (CV), which stems from the means and standard deviations of the high and low cortisol controls that accompany the competitive Elisa packages. It should have a maximum CV percentage value of 15. The intra-assay reliability is extracted from the means and standard deviations of the duplicate participant samples collected across all assays. It should have a maximum CV percentage value of 10 (Salimetrics™). The inter-assay and intra-assay reliability scores for Experiment 1 were 11.53 and 20.42, and for experiment 2 were 85.52 and 11.94 respectively.

Statistical Analyses

All statistical analyses were conducted using IBM SPSS Statistics 21.0. Significance was determined with an alpha level of $p < .05$. Bonferroni corrections were used in the cases of multiple comparisons, and the Greenhouse-Geisser correction was applied when the assumption of sphericity was violated. Outlier values that were beyond 2.5 SDs from the mean were excluded for all measures. The statistical analyses investigated group comparisons at baseline, stress responsivity, and the effects of stress on executive functioning.

Independent analyses of variance (ANOVAs) were conducted on each of the baseline variables to determine existing between-groups differences before the stress induction manipulation.

The data from Experiment 1 was analyzed to address the first objective: the acute stress responsivity and the effects of acute stress on executive functioning in older adults. A set of ANOVAs was conducted to examine stress responsivity (i.e., self-reported stress/mood and cortisol level) and check the effectiveness of the stress induction manipulation. A set of MANOVAs on executive functioning performance were then conducted to determine whether being in the stress group associated with worsened performance on the N-back and Stroop tasks.

The data from Experiment 2 was analyzed to address the second and third objectives: age differences in acute stress responsivity and the effects of acute stress on executive functioning. Similar to Experiment 1, a set of ANOVA was conducted to examine age differences in stress responsivity and as a stress-induction manipulation check. A set of MANOVAs on executive functioning performance was then conducted to address the stress effect on executive functioning performance on N-back and Stroop tasks.

Stress responsivity.

To assess stress responsivity, ANOVAs were conducted on each of the DVs: SRSS score, the positive and negative affect scores on the PANAS, and salivary cortisol (μg/dL). Salivary cortisol levels were expected to peak at the fourth time point (T4) which was to be collected 15-20 minutes post the acute stress induction, a time that is known to generate peak cortisol levels in the literature (Dickerson & Kemeny, 2004). Proportional change scores, which index the change in cortisol concentrations over time, were also computed between the second baseline values (T2) and the expected peak values (T4), as follows: $\frac{(T4-T2)}{T2}$. It was expected that participants in the stress condition would exhibit larger delta change values compared to the control groups. For Experiment 2, age was included as a between-subjects variable in the model. It was expected that older adults would exhibit significantly higher stress levels compared to young adults.

The effects of stress on executive functioning.

For both the N-back and Stroop tasks, MANOVAs were conducted for each of the dependent variables: reaction time and accuracy. To specifically examine the effect of stress on interference regulation, a Stroop interference score was calculated for RT and accuracy (Wilkinson & Yang, 2016). A ratio score was used to control for baseline group differences in processing speed or accuracy. Specifically, the Stroop reaction time interference ratio score = $(RT_{incongruent} - RT_{neutral})/RT_{neutral}$, Stroop accuracy interference ratio score = $(RT_{neutral} - RT_{incongruent})/RT_{neutral}$. MANOVAs were conducted with the interference ratio scores as DVs. It was expected that participants in the stress groups would exhibit a reduced performance (e.g., lower accuracy, longer RT, larger interference score) compared to the control group. Age was added as a between-subjects variable in Experiment 2. It was expected that the stress effect on executive functioning would be differentially larger for older relative to young adults.

Chapter 3. Experiment 1: The Effects of Acute Psychosocial Stress on Executive Functioning among Older Adults

Participant Characteristics

Fourteen older adults (age range: 65-79; *M* = 71.29, *SD* = 4.27) participated in Experiment 1. Eleven of the participants (78.57%) identified as female. The participants received, on average, 15.17 (*SD* = 4.27) years of education, starting grade one. The sample was divided into two groups, six participants underwent the acute stressor task, and eight were in a resting control condition. Participants were recruited from the Ryerson Senior Participant Pool (RSPP) and were compensated $25 for a 2-2.5 hour testing session. Participants were pre-screened via an eligibility questionnaire conducted over phone, prior to scheduling a testing session. Those who met one or more of the following exclusion criteria were deemed ineligible to participate: (a) if the participant aged below 65 years old; (b) neurological conditions (e.g., stroke, Alzheimer's); (c) history of psychological mood disorders (e.g., depression); (d) Females who are currently on hormone replacement therapy; and (e) Participants who often experience dryness in their mouth. Of the participants who completed the experiment, four were excluded for the following reasons: one due to a mood disorder, one due to an extremely low saliva yield, and two for taking medication that might compromise salivary cortisol levels. The final sample consisted of fourteen older adults. No Baseline differences were observed between the stress and control groups (*ps* > .12; Table 1).

Procedure

The procedure for Experiment 1 is outlined in Figure 1. Participants began the testing session at 1:00pm. This time window has been selected to best control for diurnal cycles of cortisol (Schoofs, Wolf, & Smeets, 2009). The informed consent was signed before testing

began. T1 (1st baseline) salivary cortisol sample was collected. Participants then completed the baseline measures and were given a 30-minute rest period. The rest period was followed by the collection of T2 (2nd baseline) salivary cortisol sample. Participants were then randomized to a stress-induction condition (n=6) or a control condition (n=8). Participants in the stress group underwent the TSST, whereas those in the control group had a 15-minute rest phase. This was

Table 1

Sample characteristics and baseline profile across conditions in Exp.1

	Tot. Sample (N=14)	OA Stress (N=6)	OA Control (N=8)	*p*
Demographics				
% Female	78.57	66.67	87.5	
Age	71.29 (4.27)	72.17 (4.26)	70.63 (4.44)	*.53*
Tot. Education[a]	15.17 (2.08)	15.60 (2.07)	14.86 (2.19)	*.57*
Stress Measures				
Stress Rating Today	2.00 (1.41)	2.17 (1.60)	1.88 (1.36)	*.72*
PSS	8.36 (5.12)	7.50 (3.78)	9.00 (6.12)	*.61*
DASS				
Depression	4.71 (6.21)	3.33 (1.63)	5.75 (8.17)	*.49*
Anxiety	2.71 (2.43)	2.33 (1.51)	3.00 (3.02)	*.63*
Stress	5.57 (4.45)	7.33 (5.75)	4.25 (2.92)	*.21*
Salivary Cortisol*	3.81 (2.28)	2.71 (1.63)	4.5 (2.45)	*.18*
Cognitive Measures				
DSST	67.57 (13.63)	61.00 (12.13)	72.50 (13.22)	*.12*
Forward Digit Span	7.21 (1.05)	7.17 (1.17)	7.25 (1.04)	*.89*
Backward Digit Span	5.07 (1.38)	5.00 (1.55)	5.13 (1.36)	*.88*

*The data is presented in M(SD) in each cell except for gender. [a]Years of formal education. *: the baseline (T1) value was used for these measures. p-values refer to group differences across condition.*

immediately followed by collecting the second PANAS and SRSS scores, as well as the T3 (zero mins post TSST) salivary cortisol sample collection. They then completed the Stroop task,

followed by the N-Back task, with a short break between the two tasks for the T4 (10-15 mins post TSST) salivary cortisol collection. Subsequently, PANAS, SRSS were collected for the third time, as well as the T5 (35 mins post TSST) salivary cortisol sample. Participants then completed a demographic and health information questionnaire and after a short recovery break, the T6 (50 mins post TSST/recovery) salivary cortisol sample was collected. The total duration of the experiment was 2-2.5 hours.

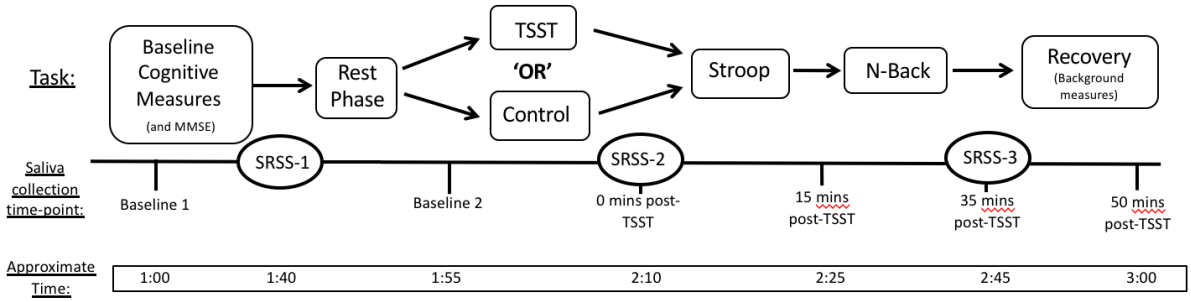

fig. 1. A diagram of the procedure for experiment 1

Results

Baseline profile.

Baseline measures of stress. One-way 2 (condition: stress vs. control) ANOVAs on behavioural stress, physiological stress, and cognitive measures revealed no significant differences between groups (*ps* > .12). The stress and control groups were matched on all baseline variables.

Stress responsivity.

Behavioural index.

SRSS. A 2 (condition: stress vs. control) × 3 (time) ANOVA, with repeated measures on the time variable, revealed no significant effects (p =.89).

PANAS. Positive affect: The 2 (condition: stress vs. control) × 3 (time) ANOVA, with repeated measures on the time variable revealed no significant effects (p = .74). *Negative affect*: the same ANOVA on the negative affect scores revealed a marginally significant effect of $F(1, 12) = 4.00$, $p = .069$, $\eta_p^2 = .25$, with the stress group (M = 12.83, SD = .69) experiencing higher rates of negative affect compared to the control group (M = 11.00, SD = .60). The model exhibited a significant time point × condition interaction, $F(1.32, 15.78) = 12.05$, $p = .002$, $\eta_p^2 = .50$. Follow-up ANOVAs were conducted for condition. After using bonferroni corrections to correct for comparisons, the analyses revealed no significant effects in either the stress ($p > .12$) or control conditions ($p > .19$).

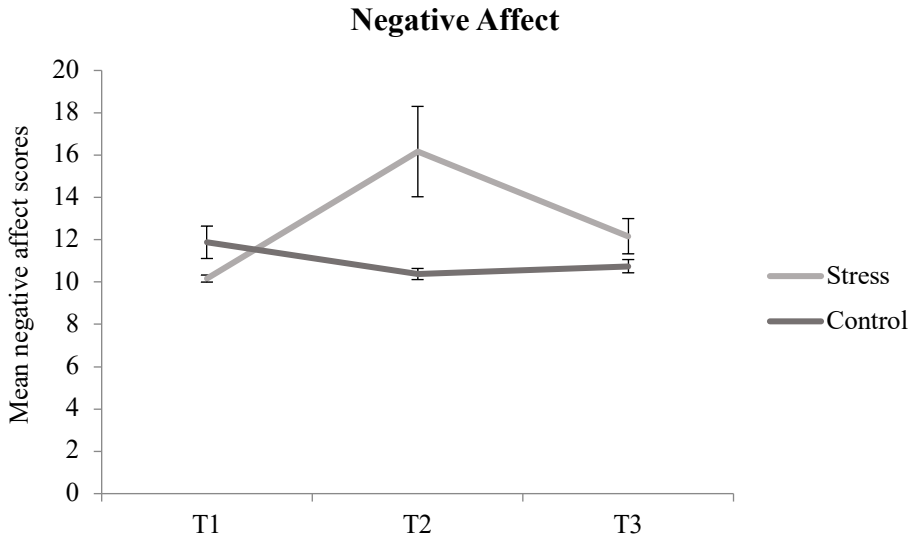

fig. 2. The negative affect scores from the PANAS, at three time points. T1: baseline; T2: immediately after stress induction; T3: recovery.

A hypothesis driven 2 (condition: stress vs. control) × 2 (Time point: pre-TSST, immediately post TSST) ANOVA was then conducted, with repeated measures on the time point variable. Between subjects analyses revealed no significant effects (p = .08). As in the full time span analyses above, within subjects effects revealed a significant condition × time points

interaction, $F(1, 12) = 13.94$, $p < .003$, $\eta_p^2 = .54$. Follow up analyses revealed a significant change in negative affect in the stress group only, where negative affect increased significantly from pre-TSST (T1: $M = 10.17$, $SD = .41$) to immediately post TSST (T2: $M = 16.17$, $SD = 5.23$), $p = .04$.

Physiological index.

Salivary cortisol. A 2 (condition: stress vs. control) × 6 (time points) repeated measures ANOVA was conducted to assess changes in cortisol levels (Figure 3) revealed no significant between subjects effects in this model ($p = .87$). Within subjects effects revealed a significant condition × time points interaction, $F(5, 45) = 2.87$, $p = .025$, $\eta_p^2 = .24$. Follow-up ANOVAs were conducted on each stress condition. After using bonferroni corrections to correct for comparisons, the analyses revealed no significant pairwise comparisons in either the stress ($p = 1.00$) or control ($p > .958$) conditions.

A hypothesis driven 2 (condition: stress vs. control) × 2 (Time point: pre-TSST, 15 mins post TSST) ANOVA was then conducted, with repeated measures on the time point variable. Between subjects analyses revealed no significant effects ($p = .61$). As in the full time span analyses above, within subjects effects revealed a significant condition × time points interaction, $F(1, 10) = 10.26$, $p = .009$, $\eta_p^2 = .51$. After using bonferroni corrections to correct for comparisons, however, the analyses revealed no significant pairwise comparisons in either the stress or control ($p > .06$) conditions.

Salivary cortisol levels in figure 3 depict an increase in salivary cortisol in the stress group after acute stress exposure ($\Delta = .58$), as well as a decrease in the salivary cortisol levels of the control group over time ($\Delta = -.22$). These results indicate that the stress manipulation was successful in inducing physiological stress.

To investigate the reliability of the cortisol assays, inter-assay and intra-assay reliability scores were calculated. The results were: intra-assay reliability (n=80) = 20.42, inter-assay reliability (n=3) = 11.53.

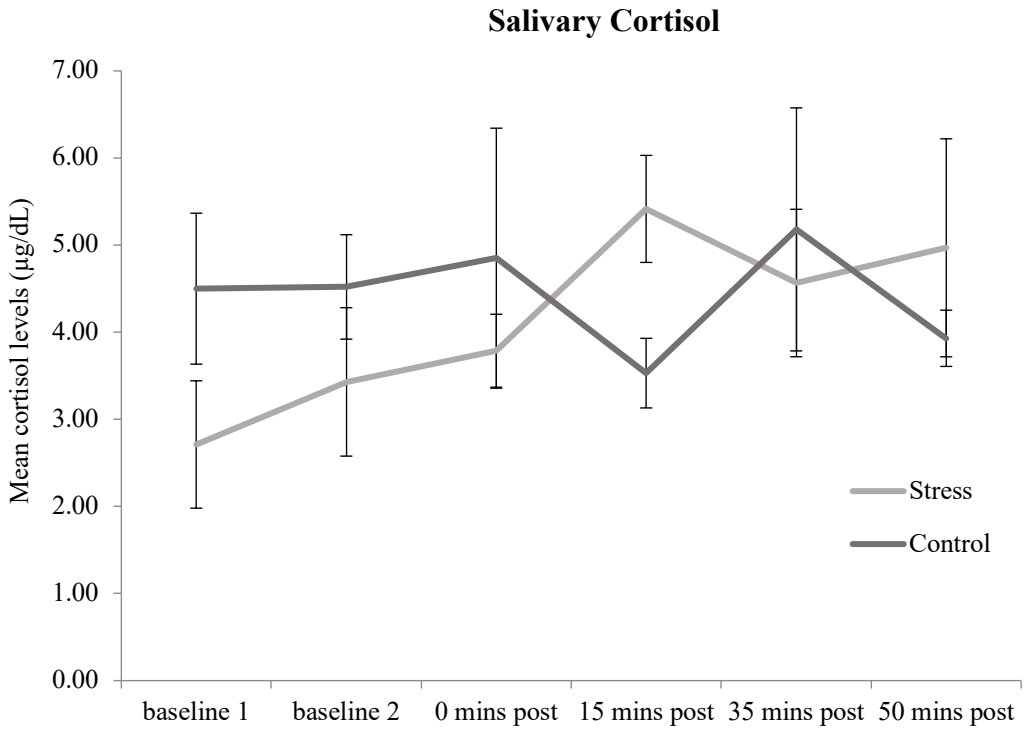

fig. 3. The mean salivary cortisol levels (in micrograms per deciliter) at five time points.

Effects of acute stress on executive functioning.

N-back task.

RT. A 2 (condition: stress vs. control) × 2 (block: 1-back vs. 3-back) MANOVA conducted on RT revealed no significant differences in RT between groups ($p > .47$).

Accuracy. A 2 (condition: stress vs. control) × 2 (block: 1-back vs. 3-back) MANOVA conducted on accuracy revealed no significant differences in accuracy between groups ($p > .58$; Table 2).

Table 2

Mean Scores on the N-back task (Exp. 1)

	Stress	Control	*p*
RT			
1back	569.82 (198.80)	641.67 (167.98)	*.53*
3back	991.45 (367.03)	776.43 (228.48)	*.47*
Accuracy			
1back	.78 (.25)	.67 (.36)	*.60*
3back	.52 (.14)	.46 (.15)	*.58*

Note. The data is presented in M(SD) in each cell. RT scores measured in milliseconds. Accuracy scores measured as percentage correct responses. p-values refer to group differences across condition.

Stroop task.

RT. A 2 (condition: stress vs. control) × 3 (trial type: congruent, incongruent, neutral) MANOVA conducted on RT revealed no significant differences in RT between groups ($p > .47$). The interference score was calculated to further examine which group showed higher interference (incongruent vs. neutral). A one-way 2 (condition: stress vs. control) ANOVA was conducted with RT interference ratio as the DV. Results revealed a significant effect of condition on interference ratio, $F(1, 10) = 5.54$, $p = .04$, $\eta_p^2 = .36$, with a higher interference ratio in the stress group ($M = .341$, $SD = .069$) compared to the control group ($M = .128$, $SD = .058$), suggesting a negative effect of stress on interference resolution in the Stroop task (Figure 5).

Accuracy. A 2 (condition: stress vs. control) × 3 (trial type: congruent, incongruent, neutral) MANOVA was conducted on accuracy. Results revealed no significant differences in accuracy between groups ($p > .70$). The interference score was calculated to further examine which group showed higher interference (incongruent vs. neutral). A one-way 2 (condition: stress vs. control) ANOVA was conducted with accuracy interference ratio as the DV. There were no significant group differences in the interference ratio ($p = .70$).

Table 3

Mean Scores on the Stroop task (Exp. 1)

	Stress	Control	*p*
RT			
Congruent	982.03 (273.86)	993.53 (195.83)	*.93*
Incongruent	1240.57 (285.03)	1132.05 (212.30)	*.47*
Neutral	940.68 (243.58)	1007.02 (200.85)	*.62*
Accuracy			
Congruent	1.00 (.00)	1.00 (.00)	--*
Incongruent	.81 (.40)	.98 (.03)	*.95*
Neutral	.99 (.02)	1.00 (.00)	*.26*

*Note. The data is presented in M(SD) in each cell. RT scores measured in milliseconds. Accuracy scores measured as percentage correct responses. p-values refer to group differences across condition.*p-value for the accuracy on congruent trials could not be calculated due to the lack of variance within groups.*

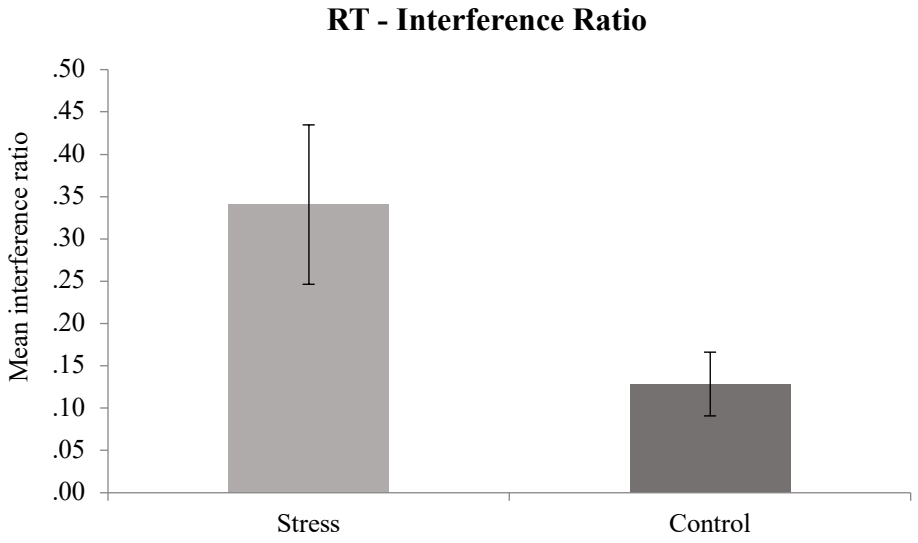

fig. 4. The mean interference ratio scores for reaction time, calculated: ($RT_{incongruent} - RT_{neutral}$)/$RT_{neutral.}$

The results of Experiment 1 revealed that the TSST was successful in inducing stress levels. The induced stress resulted in a negative effect on the speed of interference resolution, yet exhibited no effects on reaction time or accuracy in the updating and inhibition components of executive functioning. Experiment 1 provides some evidence on the negative effects of stress on executive functioning, however further research is required to confirm the findings.

Chapter 4. Experiment 2: The Effects of Acute Psychosocial Stress on Executive Functioning in Young and Older Adults

Participant Characteristics

Sixty-seven healthy adults (35 older, aged 66-93 years, *M* = 75.89, *SD* =6.89; 32 young, aged 18-28 years, *M* = 19.36, *SD* = 2.16) participated in Experiment 2. Fifty of the participants (75.76%) identified as female (1 participant had missing gender data). The participants received, on average, 14.59 (*SD* = 3.68) years of education, starting grade 1. Each age group was divided into two conditions. Among the older adults, 17 participants underwent the acute stressor task, and 18 were in a control conversation task. Among the young adults, 14 participants underwent the acute stressor task, and 18 were in a control conversation task.

The young adults (aged 18-28 years, *M* = 19.36, *SD* = 2.16) were recruited from Ryerson University's online undergraduate student pool (i.e., SONA) where they were compensated with course credit. The older adults (aged 66-93 years, *M* = 75.89, *SD* =6.89) were recruited from the Ryerson Senior Participant Pool (RSPP) and were compensated $20 for a 1.5-2 hour testing session. The older participants were pre-screened via an eligibility questionnaire conducted over the phone, prior to scheduling a testing session. If participants met one or more of the following criteria, they were deemed ineligible to participate: (a) participant is not 65 years old or older; (b) neurological conditions (e.g., stroke, Alzheimer's); (c) history of psychological mood disorders (e.g., depression); and (d) Females who are currently on hormone replacement therapy (or birth control for younger adult females). A total of 16 (11 in stress and 5 in control condition) young adults were excluded: one due to not meeting the age criteria (18-29 years), five for having a mood/neurological disorder, one for having an anxiety disorder, one due to researcher errors within the study, one due to scoring below 26 on the MMSE, one for being on a medication that

may compromise salivary cortisol levels, and finally six for scoring higher than 'severe' on the DASS-21 , which is a score of 27 or higher on the depression subscale, 19 or higher on the

Table 4

Sample Characteristics and Baseline Profile across Age Group and Stress Condition (Exp. 2)

	Total Sample (n = 67)	Young		Older		*P*
		Stress (n = 14)	Control (n = 18)	Stress (n = 17)	Control (n = 18)	
Demographics						
% Female	75.76	85.71	88.89	70.59	58.82	
Age	49.80 (28.87)	19.23 (1.59)	19.47 (2.55)	75.12 (5.36)	76.61 (8.18)	*<.001* [T]
Tot. Education[a]	14.59 (3.68)	13.93 (1.86)	13.29 (1.16)	15.25 (2.70)	13.88 (8.10)	*.15*
Stress Measures						
Stress Rating Today	3.96 (2.22)	4.64 (1.82)	4.72 (2.40)	3.59 (1.84)	3.06 (2.41)	*.22*
PSS	14.52 (6.27)	19.07 (3.81)	17.28 (5.30)	11.88 (5.73)	10.72 (5.93)	*.007* [T]
DASS						
Depression	5.10 (5.28)	8.57 (7.25)	5.00 (4.51)	4.12 (4.66)	3.44 (3.68)	*.28*
Anxiety	5.04 (4.95)	8.43 (5.15)	6.89 (4.86)	2.35 (2.26)	3.11 (4.71)	*.009* [T]
Stress	9.97 (8.13)	15.00 (8.66)	10.89 (9.41)	7.18 (6.67)	7.18 (5.86)	*.44*
Salivary Cortisol (µg/dL)*	5.02 (2.64)	7.44 (4.38)	6.03 (3.02)	3.07 (1.76)	4.16 (1.57)	*.01* [T]
Cognitive Measures						
DSST	71.99 (16.24)	88.07 (10.97)	77.94 (13.73)	66.29 (13.07)	58.89 (10.84)	*.001* [T]
Forward Digit Span	6.60 (1.46)	6.86 (1.46)	6.72 (1.41)	6.41 (1.58)	6.44 (1.46)	*.50*
Backward Digit Span	4.51 (1.19)	4.36 (1.15)	4.22 (1.06)	5.12 (1.41)	4.33 (.97)	*.90*

Note. The data is presented in M(SD) in each cell except for gender. [a]*Years of formal education. *: the baseline (T1) value was used for salivary cortisol* [T]*Significant group differences. p-values refer to differences between the four groups (2 age, 2 stress).*

anxiety subscale, and 33 or higher on the stress subscale. Due to feasibility purposes, only eight of the excluded participants were replaced, leaving a total of 32 young adult participants. Furthermore, five older adults were excluded: one due to not meeting the criteria on the DASS-21, one for scoring below 26 on the MMSE, and three for taking medication that might

compromise the salivary cortisol levels. None of the older adults' data was replaced, leaving a total of 35 older adults in the final sample.

Baseline comparisons between age groups revealed significant differences between young and older adults in PSS scores, and DASS-21 anxiety scores. Baseline comparisons between the stress groups revealed significant differences in the DSST. Due to the small sample size, however, these potential covariates were not accounted for, so they would not over fit the model. There were no significant age × condition × baseline measure interactions.

Procedure

The procedure for Experiment 2 is outlined in Figure 2. Participants began the testing session at 1:00pm. This time window has been selected to best control for diurnal cycles of cortisol (Schoofs et al., 2009). The informed consent was signed at the beginning of the study, followed by the collection of the T1 (1st baseline) salivary cortisol sample. Participants then completed the baseline measures, followed by the collection of T2 (2nd baseline) salivary cortisol sample. Subsequently, participants in the stress groups underwent the TSST, whereas those in the control groups completed the conversation task. This was immediately followed by collecting the second PANAS and SRSS scores, as well as the T3 (0 mins post TSST) salivary cortisol sample collection. They then completed the two executive functioning tasks, the order of which was counterbalanced across participants. Subsequently, PANAS, SRSS were collected for the third time, as well as the T4 (20 mins post TSST) salivary cortisol sample. Participants then completed a demographic and health information questionnaire, as well as the MMSE. Finally, the T5 (35 mins post TSST/recovery) salivary cortisol sample was collected. The total duration of the experiment was 1.5-2 hours.

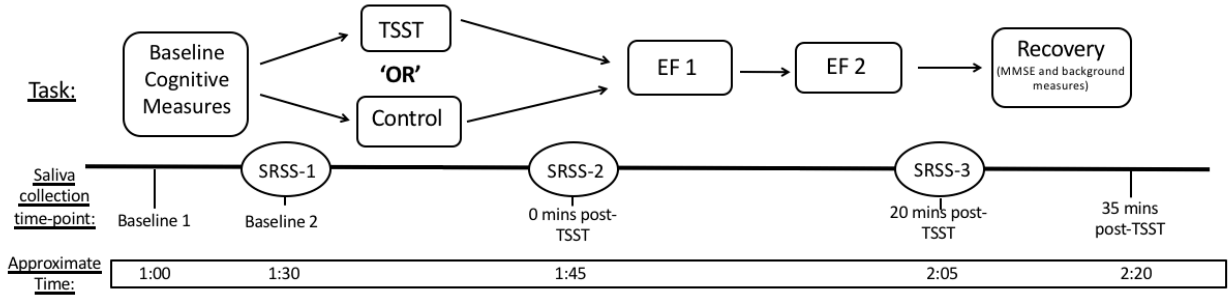

fig. 5. A diagram of the procedure for experiment 2

Results

Baseline profile.

Baseline measures of behavioural stress. A 2 (age: young vs. older) × 2 (condition: stress vs. control) multivariate ANOVA on behavioural stress measures revealed a significant main effect of age for all the baseline measures. Compared to young adults, older adults reported significantly lower perceived stress, $F(1, 63) = 27.55, p < .001, \eta_p^2 = .30$, lower self-reported stress levels on the day of testing, $F(1, 63) = 6.75, p = .012, \eta_p^2 = .10$, and lower scores on the DASS-21 subscales of depression, $F(1, 63) = 5.86, p = .018, \eta_p^2 = .09$, anxiety $F(1, 63) = 21.00$, $p < .001, \eta_p^2 = .25$, and stress $F(1, 63) = 8.27, p = .006, \eta_p^2 = .12$. The results suggest that older adults' perceived stress was lower than that of young adults at baseline. There were no significant condition effects ($p > .09$), and no significant age by condition interaction ($p > .22$).

Physiological markers of stress at baseline. A 2 (age: young vs. older) × 2 (condition: stress vs. control) multivariate ANOVA on physiological stress measures revealed a significant main effect of age on salivary cortisol levels, where older adults produced significantly lower levels of salivary cortisol compared to young adults at T1, $F(1, 19) = 10.53, p = .004, \eta_p^2 = .36$. The results were also consistent with the analysis on behavioural measures suggesting a lower

level of stress at baseline for older adults. There were no other significant effects or interactions ($p > .18$).

Cognitive measures at baseline. A 2 (age: young vs. older) × 2 (condition: stress vs. control) multivariate ANOVA on baseline cognitive measures revealed significantly poorer performance on the DSST in older adults than in young adults, $F(1, 63) = 54.82$, $p < .001$, $\eta_p^2 = .42$. Furthermore, the stress groups performed significantly better on the DSST than the control groups, $F(1, 63) = 8.45$, $p = .005$, $\eta_p^2 = .12$. There were no other significant effects (*ps,* >.18).

Stress responsivity.

Behavioural index.

SRSS. A 2 (age: young vs. older) × 2 (condition: stress vs. control) × 3 (time points) repeated measures ANOVA on self-reported stress depicted significant main effects of age, $F(1, 63) = 10.70$, $p = .002$, $\eta_p^2 = .15$, where young adults ($M = 4.69$, $SE = .345$) reported higher stress than older adults ($M = 3.13$, $SE = .327$). There was a main effect of time point, $F(2, 126) = 6.68$, $p = .002$, $\eta_p^2 = .10$, which was qualified by a time point × age interaction, $F(2, 126) = 3.12$, $p = .048$, $\eta_p^2 = .05$, as well as by a time point × Stress interaction, $F(2, 126) = 16.41$, $p < .001$, $\eta_p^2 = .21$. All the other effects were not significant ($ps > .08$; Figure 6).

To follow up the time point by age interaction, a repeated measures ANOVA was conducted to examine the effect of time point for each age group. The results showed significant time point effect in young adults, $F(2, 37) = 16.11$, $p < .001$, $\eta_p^2 = .47$, but not in older adults ($p = .051$). Specifically, young adults showed a significant drop in self-reported stress at T3 (recovery: $M = 4.22$, $SD = 2.17$) relative to T1 (baseline: $M = 4.89$, $SD = 2.33$) and T2 (immediately post induction: $M = 4.84$, $SD = 2.40$).

To follow up the time point by condition interaction, a repeated measures ANOVA was conducted to examine the effect of time point within each stress condition. The results showed significant time point effect in the stress condition, $F(2, 36) = 16.50$, $p < .001$, $\eta_p^2 = .48$, but not the control condition ($p = .29$). Specifically, the stress group showed a significant increase in self-reported stress increase in self-reported stress levels from T1 (baseline: $M = 3.77$, $SD = 2.22$) to T2 (immediately post induction; $M = 4.90$, $SD = 2.10$), followed by a significant decrease in T3 (recovery: $M = 3.68$, $SD = 2.00$). As for the control condition, there was a significant drop in self-reported stress levels from baseline (T1; $M = 3.93$, $SD = 2.31$), to immediately post stress-filler time (T2; $M = 3.42$, $SD = 2.23$).

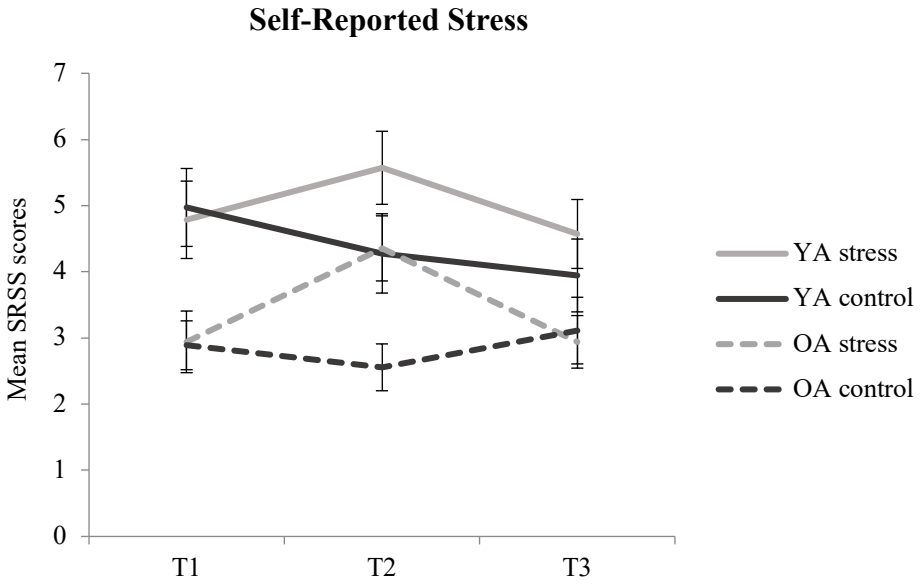

fig. 6. Self-reported stress scale (SRSS) ratings on a scale 1 (lowest stress)-10 (highest stress), over three time points: T1: baseline; T2: immediately post the TSST; T3: recovery.

To specifically examine the stress induction effect, a 2 (condition: stress vs. control) × 2 (Time points: T1 vs. T2) mixed model ANOVA was conducted, with repeated measures on the time point variable. The results showed that only the stress condition showed a significant

increase from T1 (baseline: *M*= 3.77, *SD*= 2.22) to T2 (immediately post induction; *M*= 4.90, *SD*= 2.10), suggesting the stress induction was effective.

Positive affect. A 2 (age: young vs. older) × 2 (condition: stress vs. control) × 3 (time points) repeated measures ANOVA on the positive affect (PA) score on the PANAS (Figure 7) revealed a significant effect of Age, $F(1, 63) = 14.27, p < .001, \eta_p^2 = .19$, with an overall higher PA score in older adults ($M = 34.58, SE = 1.30$) relative to young adults ($M = 27.95, SE = 1.30$). There was also a significant main effect of time point, $F(1.71, 107.89) = 7.94, p < .001, \eta_p^2 = .11$, which was qualified by a significant time point × Condition interaction, $F(1.71, 107.89) = 4.79, p = .014, \eta_p^2 = .07$. Follow-up analyses showed that the stress group depicted a significant drop in PA from baseline (T1: *M*= 32.58, *SD*= 6.69) to post-induction (T2: *M*= 30.32, *SD*= 7.65) and post executive function tasks (T3: *M*= 29.58, *SD*= 8.26); *ps* < .002. The control group did not change between T1 ($M = 32.28, SD = 8.29$) and T2 (*M*= 33.03, *SD*= 9.06), $p = .99$, but

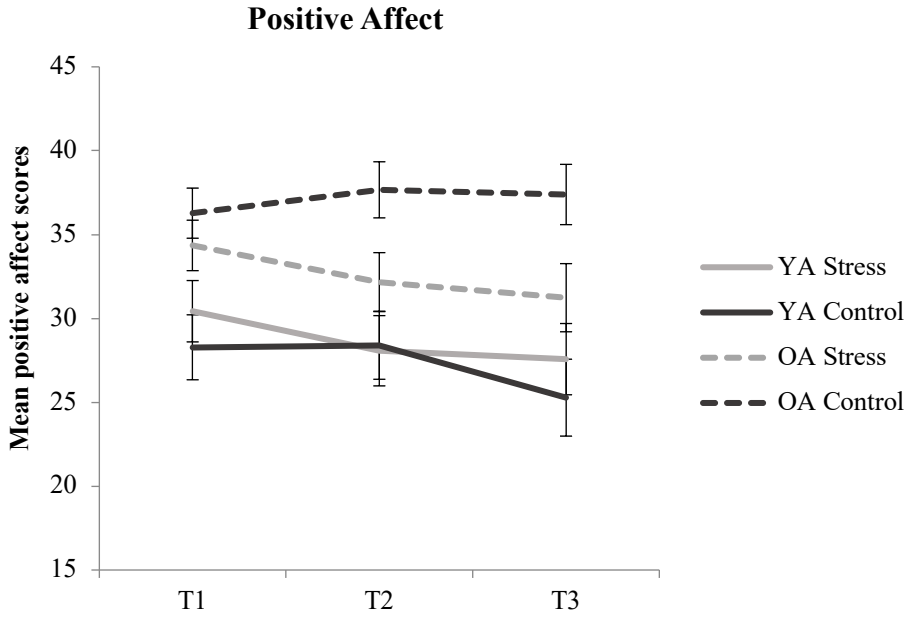

fig. 7. The positive affect scores from the PANAS, at three time points. T1: baseline; T2: immediately after stress induction; T3: recovery.

experienced a decrease in PA from T2 (*M*= 33.03, *SD*= 9.06) to T3 (*M*= 31.33, *SD*= 10.58M), *p* = .016. All other effects were non-significant (*p*s > .10).

To examine age differences in stress responsivity, a 2 (group: young stressed vs. older stressed) × 3 (time) multivariate ANOVA was conducted, with positive affect as the DV. Results revealed no significant differences between young and older adults (*ps* > .11).

Negative affect. A 2 (age: young vs. older) × 2 (condition: stress vs. control) × 3 (time points) repeated measures ANOVA on the negative affect (NA) PANAS score (Figure 8) revealed a significant main effect of time point, $F(2, 124) = 6.85, p = .002, \eta_p^2 = .10$, which was qualified by a time point × stress group interactions, $F(2, 124) = 11.07, p < .001, \eta_p^2 = .15$. Follow-up analyses revealed that the stress group showed a significant increase in NA from T1 (*M*= 11.97, *SD*= 2.01) to T2 (*M*= 14.63, *SD*= 3.87), *p* = .003, suggesting that TSST successfully induced negative affect. The stress group further exhibited a drop in NA from T2 (*M*= 14.63, *SD*= 3.87) to T3 (*M*= 12.00, *SD*= 2.24), suggesting a recovery from the stress induction. The

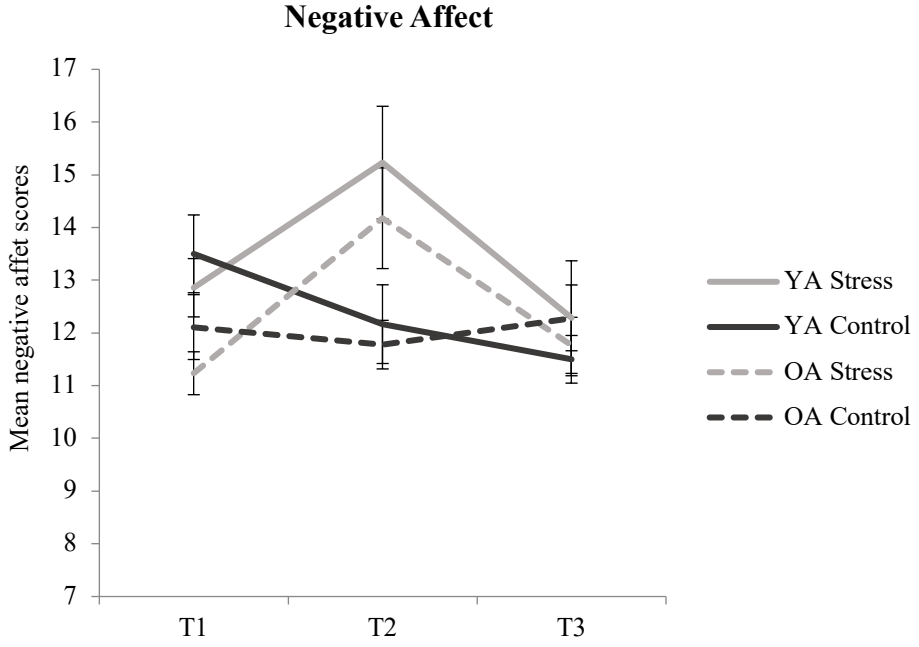

fig. 8. The negative affect scores from the PANAS, at three time points. T1: baseline; T2: immediately after stress induction; T3: recovery.

control group did not exhibit any significant time point differences, *ps* > .13. There were no other significant interactions (*p* > .09).

To examine age differences in stress responsivity, a 2 (group: young stressed vs. older stressed) × 3 (time) multivariate ANOVA was conducted, with negative affect as the DV. Results revealed a significant age difference at T1 (baseline), $F(1, 28) = 5.31$, $p = .03$, $\eta_p^2 = .16$, where young adults (M= 12.85, SD= 2.15) reported higher levels of negative affect than older adults (M= 11.24, SD= 1.68). There were no significant age differences in negative affect post stress induction (*ps* > .47).

Physiological index.

Salivary cortisol. A 2 (age: young vs. older) × 2 (condition: stress vs. control) × 5 (time points) repeated measures ANOVA on salivary cortisol levels across five time points (Figure 9) revealed a significant effect of age, $F(1, 35) = 8.58$, $p = .006$, $\eta_p^2 = .20$, where young adults (M = 6.46, SE = .53) depicted higher salivary cortisol levels than older adults (M = 4.32, SE = .501). Furthermore, the results revealed a significant time point × condition interaction, $F(2.42, 84.82) = 3.07$, $p = .042$, $\eta_p^2 = .08$. Follow-up ANOVAs revealed no significant effects between any two time points for either the stress (p > .36) or control (p > .54) groups. To specifically examine the stress induction effect, a 2 (condition: stress vs. control) × 2 (Time points: T2 vs. T4) mixed model ANOVA was conducted, with repeated measures on the time point variable. The results depicted a significant condition × time point interaction, $F(1, 39) = 8.03$, $p = .007$, $\eta_p^2 = .17$, where only the stress condition revealed a significant increase from T2 (M= 4.87, SD= .752) to T4 (M= 7.38, SD= 1.14), suggesting the stress induction was effective. There were no other significant interactions in the model (p > .11).

To examine age differences in stress responsivity, a 2 (group: young stressed vs. older stressed) × 5 (time) multivariate ANOVA was conducted, with salivary cortisol levels as the DV. Results revealed significant age difference at T1 (baseline 1), $F(1, 15) = 6.92, p = .02, \eta_p^2 = .32$, and at T4 (expected peak time), $F(1, 15) = 4.80, p = .045, \eta_p^2 = .24$. At both of these time points, stress reactivity was significantly higher among young adults compared to older adults. No significant age differences were present at any other time point (*ps* > .09).

Delta change proportion values depicted an increase in salivary cortisol after acute stress exposure among both age groups (Young adults: Δ = .82; older adults: Δ = .05). Moreover, the delta change proportion values exhibited a decrease in the salivary cortisol levels in the control condition for both age groups (Young adults: Δ = -.18; older adults: Δ = -.14).

To investigate the reliability of the cortisol assays, inter-assay and intra-assay reliability scores were calculated. The results depicted an intra-assay reliability of (n=221) = 11.94, and an inter-assay reliability of (n=9) = 85.52.

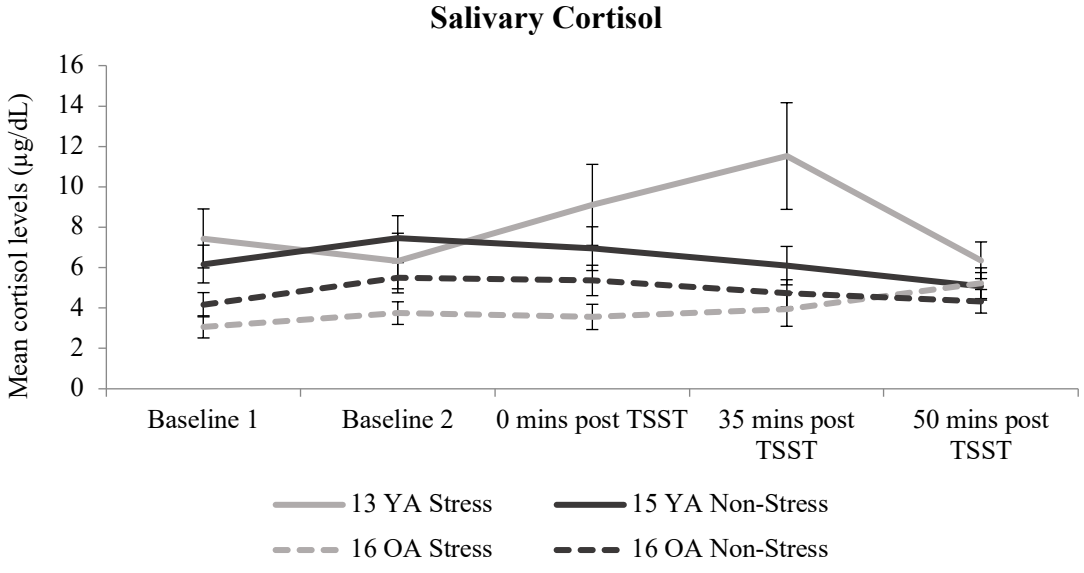

fig. 9. The mean salivary cortisol levels (in micrograms per deciliter) at five time points.

The differential effects of stress on executive functioning in young and older adults.

Three-way interactions were investigated in a 2 (age: young vs. older) × 2 (condition: stress vs. control) × 2 (block: 1 back vs. 3 back) MANOVA for N-back and a 2 (age: young vs. older) × 2 (condition: stress vs. control) × 3 (trial type: congruent, incongruent, neutral) MANOVA for Stroop, on the DVs: RT and accuracy. The 2 (age: young vs. older) × 2 (condition: stress vs. control) between-subjects Univariate ANOVA was also conducted on the Stroop ratio interference scores calculated based on RT and accuracy. The interactions were to address whether stress impacts reaction time or accuracy in executive functioning tasks differently across young and older adults. There were no significant three-way interactions in any of the models. The results indicate that age has no effect on the relationship between stress and executive functioning performance.

N-back task.

RT. The MANOVA on RT revealed a significant difference between young and older adults in the 1-back task only, $F(1, 61) = 7.25, p = .009, \eta_p^2 = .11$, where older adults ($M$ = 539.97, SD = 171.60) were slower in response time compared to young adults (M = 683.44, SD = 238.60; p = .009). There were no other group differences in the model ($ps > .09$).

Accuracy. The MANOVA on accuracy revealed significant differences between young and older adults in both blocks: 1-back, $F(1, 61) = 11.60, p < .001, \eta_p^2 = .16$; and 3-back, $F(1, 61) = 12.64, p < .001, \eta_p^2 = .17$, where older adults exhibited reduced accuracy compared to young adults ($ps = .001$). There were no other significant differences ($ps > .19$).

Stroop task.

RT. The MANOVA on RT revealed significant differences between young and older adults in all trial types: Congruent, $F(1, 59) = 15.79, p < .001, \eta_p^2 = .21$; incongruent, $F(1, 59) =$

Table 5

Mean Scores on the N-back task (Exp. 2)

	YA Stress	YA Control	OA Stress	OA Control	*p*
RT					
1back	560.20 (191.74)	524.51 (158.78)	725.42 (252.93)	643.79 (224.10)	*.04*[T]
3back	758.23 (228.27)	715.04 (225.59)	877.61 (232.79)	809.30 (291.77)	*.27*
Accuracy					
1back	0.89 (.10)	0.90 (.09)	0.77 (.21)	0.76 (.17)	*.01*[T]
3back	0.73 (.11)	0.71 (.11)	0.64 (.14)	0.56 (.16)	*.003*[T]

Note. The data is presented in M(SD) in each cell. RT scores measured in milliseconds. Accuracy scores measured as percentage correct responses. [T]*Significant group differences. p-values refer to differences between the four groups (2 age, 2 stress).*

22.40, $p < .001$, $\eta_p^2 = .28$; neutral, $F(1, 59) = 24.14$, $p < .001$, $\eta_p^2 = .29$, where older adults exhibited slower performance compared to young adults on all trial types. There were no other significant differences (*ps* > .15). The ANOVA on the RT interference ratio score revealed no significant main effects or interactions, *p*s >.15.

Table 6

Mean Scores on the Stroop task (Exp. 2)

	YA Stress	YA Control	OA Stress	OA Control	*p*
RT					
Congruent	741.43 (123.94)	759.10 (164.22)	931.89 (182.62)	1035.25 (344.59)	*.001*[T]
Incongruent	820.64 (142.07)	880.78 (218.19)	1103.61 (217.36)	1239.31 (381.49)	*<.001*[T]
Neutral	709.94 (86.37)	710.17 (127.91)	934.36 (151.76)	1048.74 (366.35)	*<.001*[T]
Accuracy					
Congruent	0.98 (.03)	0.97 (.03)	1.00 (.01)	0.99 (.02)	*.03*[T]
Incongruent	0.96 (.04)	0.92 (.06)	0.97 (.05)	0.95 (.07)	*.12*
Neutral	0.96 (.04)	0.97 (.04)	1.00 (.00)	0.98 (.03)	*.004*[T]

Note. The data is presented in M(SD) in each cell. RT scores measured in milliseconds. Accuracy scores measured as percentage correct responses. . [T]*Significant group differences. p-values refer to differences between the four groups (2 age, 2 stress).*

Accuracy. The MONOVA on accuracy revealed significant differences between young and older adults in the congruent, $F(1, 59) = 7.52, p = .008, \eta_p^2 = .11$, and neutral, $F(1, 59) = 10.41, p = .002, \eta_p^2 = .15$, trial types, where older adults exhibited *greater* accuracy compared to young adults. There were no age differences in performance on the incongruent trial ($p = .31$). Results also revealed significant differences between the stress and control groups on the incongruent trial, $F(1, 59) = 4.63, p = .04, \eta_p^2 = .07$, where the stress group ($M = .967, SE = .01$) exhibited greater accuracy than the control group ($M = .936, SE = .01$). There were no other significant differences ($ps > .24$).

The ANOVA on the accuracy interference ratio score (Figure 10) revealed a significant effect of condition, $F(1, 59) = 4.51, p = .04, \eta_p^2 = .07$, with a lower interference score in the stress group ($M = .02, SD = .054$) compared to the control group ($M = .04, SD = .06$). The results indicate that stress *enhances* accuracy performance in the Stroop task. Other effects were non-significant, $ps > .10$.

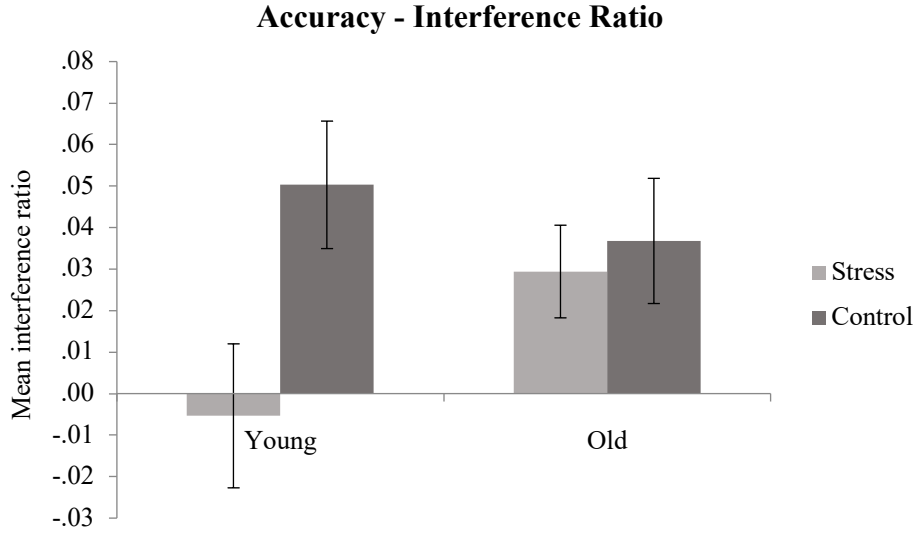

fig. 10. The mean interference ratio scores for accuracy, calculated: $RT_{neutral} - RT_{incongruent})/RT_{neutral}$..

The results of Experiment 2 revealed that the TSST was successful in inducing stress levels in both age groups. The induced stress, however, did *not* exhibit negative effects on executive functioning, but rather a positive impact on the inhibition component, where participants in the stress group performed more accurately than those in the control group. Contrary to our hypothesis, no differential effects were found in the relationship between stress and executive functioning between young and older adults. The findings in Experiment 2 did not support the findings in Experiment 1, which calls for further research to better understand the complex relationship between stress and executive functioning.

Chapter 5: General Discussion

Acute stress is a common occurrence in everyday life. Understanding its impacts on cognitive functioning, in instances such as planning and decision making, is imperative in building a better understanding of human behaviour. As the aging population continues to grow, so does the importance of understanding how the effects of stress on cognition might be sensitive to age. Recently, the effects of cortisol on the prefrontal cortex have become evident. Considering that the pre-frontal cortex is an essential brain structure for executive functioning performance, it can be extrapolated that stress potentially impacts executive functioning. The current thesis examined three objectives: age differences in stress reactivity, the effects of acute psychosocial stress on executive functioning, and whether the relationship between acute stress and executive functioning differs between young and older adults.

Age Differences in Stress Responsivity

Older adults are more reactive to acute stressors compared to young adults (Kudielka et al., 2004a). Thus, in the current thesis, it was expected that this finding would be replicated. Contrary to the hypothesis, however, there were no significant differences in stress responsivity between both age groups. In fact, young adults generally exhibited higher stress levels compared to older adults. The lack of significant differences in stress responsivity across age groups is not a novel finding, as it had been exhibited in the past. A study that investigated the effects of acute stress by examining salivary alpha amylase, cortisol, and cardiovascular activity across older adults, young adults, and children, found no age differences in stress responsivity (Strahler, Mueller, Rosenloecher, Kirschbaum, & Rohleder, 2010). Other studies have shown no differences between young and older adults in positive or negative affect reports or in self-

reported stress levels (e.g., Röcke, Li, & Smith, 2009; Stawski, Sliwinski, Almeida, & Smyth, 2008).

The results are potentially explained by characteristics of the older adult sample. Due to recruitment from the RSPP, the older adult participants' physical and cognitive health was above the average physical and cognitive health of the aging population. Furthermore, participants' recorded healthy diet and exercise habits are indicators of a healthy physiological stress response system. It may be that they were at a level of health where their stress responses were similar to those of young adults. This notion supports the existing suggestion that cortisol patterns can be maintained into older age, and that variability in cortisol concentrations might be due to individual variability as opposed to age difference (Ice, Katz-Stein, Himes & Kane, 2004).

The Effects of Acute Stress on Executive Functioning

Regarding the effects of stress on executive functioning measures, the results were mixed. All N-back task results were non-significant, indicating no effect of stress on executive functioning. The Stroop task exhibited some significant results which were conflicting, indicating a negative effect of stress on some aspects (RT) of executive functioning in experiment 1, and a positive effect of stress on other aspects (accuracy) of executive functioning in experiment 2. The inconsistent results support Anguera et al.'s (2012) view that inhibitory processes are independent from one another, and thus are affected by environmental factors (such as age or stress) differently.

The stress enhancement effect may be explained by the Yerkes–Dodson law (Yerkes et al., 1908). The induced levels of acute stress may have been the required dose of arousal the participants needed to optimize their performance. Perhaps stress induced only at extreme levels would depict a reduction in executive functioning performance. In fact, previous research shows

that increases in cortisol levels have improved memory performance (e.g., Abercrombie et al., 2003; Buchanan & Lovallo, 2001). Other studies have exhibited that the acute stressor impacted some aspects of cognition negatively, while simultaneously impacting other aspects positively within the same domain (Duncko, Johnson, Merikangas, & Grillon, 2009).

Age Differences in the Effects of Acute Stress on Executive Functioning

The results exhibited no effect of age on the relationship between stress and executive functioning. The null results might be due to the underpowered sample. The sample consisted of 67 participants and a power of .47. To achieve the desired power of .95, and allow the possibility of a significant three-way interaction, the sample should consist of 279 participants. For this reason, results and conclusions must be treated with caution.

The hypothesis that stress would have a more detrimental impact on executive functioning in older, as opposed to young, adults was based on two predictions: that older adults would exhibit greater stress reactivity than young adults, and that stress would have a negative impact on executive functioning. As neither of those predictions was robustly confirmed in the current thesis, it calls the predicted relationship of age, stress, and executive functioning into question. The mixed literature in the fields of stress, cognition, and aging highlights the complexity of such a relationship. Many confounding variables, such as gender, years of education, dietary choices, socioeconomic status, and previous abuse or trauma could affect its direction. Considering the novelty of this hypothesis, more research accounting for broader areas of cognition and co-variates is required before conclusions can be made.

Limitations and Future Directions

The current thesis sheds light on an important and novel area of research. However, a number of limitations, as well as future directions in research, should be noted.

Firstly, the sample size in both experiments was small. Experiment 1 consisted of a sample of 14, with a power of .14, while experiment 2 consisted of a sample of 67, with a power of .47. The experiments must be replicated with larger samples to confirm the results, and to help control for baseline differences. Group differences in baseline stress scores were exhibited. In addition to the small sample size, a contributing factor to this difference could be the time of awakening. The diurnal cortisol cycle fluctuates throughout the day, the human body releasing the highest amount of cortisol at waking, which declines throughout the day. This was controlled for in the experiment by having all participants begin the experiment at the same time (1:00pm), however it did not control for the time of waking among participants. The younger adult participants awoke at a generally later time than the older adults, so it is possible that their data was collected a slightly difference phase in their diurnal cycle, explaining the different stress scores at baseline.

Furthermore, the samples of both experiments consisted of mostly female participants. Previous work revealed robust sex differences in the human stress system (e.g., Kajantie & Phillips, 2006), as well as sex differences in the effects of stress on cognition in rodents (Ter Horst, De Kloet, Schächinger, & Oitzl, 2012), the differences being partly attributed to the estrous cycle in females (Luine, 2002). Although such results have yet to be evidenced in human subjects, it is imperative to take sex differences into account when investigating the effects of stress in human samples. Thus, having a sex matched sample, and including sex as a covariate in future analyses models is essential. Additionally, examining other age groups such as middle-aged adults would be a beneficial addition to the existing literature on age differences in the context of acute stress and executive functioning.

It should also be noted that, in Experiment 2, the researcher also acted as the confederate during the TSST phase on multiple occasions, due to the lack of available research assistants to act as confederates. Such an adjustment may have impacted the stress manipulation in the experiment. For example, it is possible that participants' stress levels would have remained elevated after the TSST was complete, because the remainder of the study was carried out by the confederate. Alternatively, the TSST may not have had enough of an impact on participants' stress levels, as they have already interacted with the confederate and established rapport. As such, the stress manipulation was not fully controlled, and thus the effects of stress on executive functioning may have been dampened.

Moreover, the salivary cortisol collection method was not ideal. Salivary cortisol was collected by placing a swab underneath the participant's tongue for one minute, collecting three swabs for each time point. In the case of older adults, who often experience a dryness in the mouth (Gerdin, Einarson, Jonsson, Aronsson, & Johansson, 2005), the amount of saliva collected was at times insufficient and needed to be diluted, compromising the quality of the results. Using other saliva collection methods, such as passive drool (Poll et al., 2007), might ensure a larger quantity of saliva for the cortisol assay process, and might eliminate the need to dilute samples. Furthermore, the inter- and intra-assay reliability scores indicated poor reliability across assays, which may have compromised the results. Analyzing the cortisol data professionally, or having the assays done by more seasoned assay researchers would improve the quality of the data analyzed. Additionally, investigating the effect of acute stress using other measurement tools would help us gain insight on the specific behavioural and physiological functions that are affected by acute stress. Some examples include using the Visual Analogue Scale (VAS; Lesage,

Berjot, & Deschamps, 2012) or the State Trait Anxiety Inventory (STAI; Rimmele et al., 2007) as behavioural measures, and plasma cortisol as a physiological measure.

The executive functioning tasks also contained some limitations. The outcome variables assessed in the executive functioning tasks, reaction time and accuracy may not have been sensitive enough to detect the impact of the acute stressor. Specifying the research question to certain executive functioning components would help ensure the validity and proper interpretation of the testing measures selected. Another limitation might be the time-limit programmed in the N-back task. The N-back task provided participants with only two seconds to provide a response. Had participants been given a bigger window of response (e.g., 4s), group differences may have become evident. Investigating the effects of acute stress on executive functioning using other executive functioning assessment tools would also help us gain perspective. Examples of such tasks are the flanker task (Eriksen & Eriksen, 1974) and the Go-No-Go task (Gomez, Ratcliffe, & Perea, 2007). Using different tasks would provide clarity regarding the degree to which different EF components are sensitive to acute stress exposure.

A final limitation is performance variability depending on time of day. It is well established that older adults tend perform better on cognitive functioning tasks in the morning hours, while young adults tend to perform better in the afternoon hours (Hasher, Goldstein, & May, 2005). Considering that our experiments were only conducted in the afternoon (1:00pm), this may have put older adults at a disadvantage, with respect to comparing young and older adults on cognitive performance. Although the results do not depict significant age differences in executive functioning performance, one must wonder whether older adults' performance would have been enhanced had they completed the study earlier in the day.

Chapter 6: Conclusions and Implications

The mixed results of the current thesis encourage further investigation into the effects of acute stress on executive functioning. We live in a time where people of all ages experience high levels of stress on a daily basis. The notion that stress might be helpful to one's cognitive capacity—even if only from a limited context—can be very beneficial in helping individuals cope, and even thrive, in the demanding environments we live in. It is imperative to dedicate more research to stress reactivity, how it changes across the adult life span, and how it impacts cognition. Such research would contribute to the understanding of the costs and benefits of stress on our mental and physical functions. The knowledge gained from this research can be implemented in applicable settings, such as in the development of programs that promote healthy living and optimal aging.

Appendices

Appendix 1: The self-reported stress scale

Self-Report Stress Scale

Please *circle* the level that best describes your current feelings of stress on a scale from 1-10, with 1 being very low levels and 10 being very high levels of stress.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Low stress High stress

Appendix 2: The TSST topic of presentation sheet for young adults (Exp. 1)

Insurance Company List

Please use this list to guide your speech on insurance plans. Utilize any knowledge you have about the following insurance companies to inform and guide the information that you put into and ultimately talk about in your speech. *Remember, even if you do not know particular information regarding each or any of the following insurance companies, please use your best judgment or inferences as to what each insurance company may offer and use that to guide your speech as well.*

- State Farm
- The Personal
- Johnson
- TD Insurance
- Sun Life Financial
- Blue Cross
- Aviva Canada
- Manulife Financial

Appendix 3: The TSST topic of presentation sheet for older adults (Exp. 1 & 2)

Social Media List

Please use this list to guide your speech on social media. Utilize any knowledge you have about the following social media outlets to inform and guide the information that you put into and ultimately talk about in your speech. *Remember, even if you do not know particular information regarding each or any of the following forms of social media, please use your best judgment or inferences as to what each form of social media may consist of and use that to guide your speech as well.*

- Facebook
- Youtube
- Twitter
- Instagram
- Pinterest
- Google+
- Linkedin
- Tumblr

Appendix 4: The control conversation topic sheet for young and older adults (Exp. 1)

Worksheet

For the next 5 minutes, please list and describe as many topics as possible that you are familiar with and enjoy discussing. First, please list topics that you enjoy. Second, go into detail about why you enjoy such things. Try to be as detailed as possible in your responses.

Appendix 5: The TSST arithmetic task for young and older adults (Exp. 1 & 2)

Arithmetic task

“We now want you to solve a calculation task. Please count aloud backwards from 2023 by 17. Please calculate as quickly and correctly as possible. Should you miscalculate, we will point out your mistake and you have to start all over again. Do you have any questions?" “Begin”

2023	1683	1343	1003	663	323
2006	1666	1326	986	646	306
1989	1649	1309	969	629	289
1972	1632	1292	952	612	272
1955	1615	1275	935	595	255
1938	1598	1258	918	578	238
1921	1581	1241	901	561	221
1904	1564	1224	884	544	204
1887	1547	1207	867	527	187
1870	1530	1190	850	510	170
1853	1513	1173	833	493	153
1836	1496	1156	816	476	136
1819	1479	1139	799	459	119
1802	1462	1122	782	442	102
1785	1445	1105	765	425	85
1768	1428	1088	748	408	68
1751	1411	1071	731	391	51
1734	1394	1054	714	374	34
1717	1377	1037	697	357	17
1700	1360	1020	680	340	0

Should the participant miscalculate?
"Wrong. Start again from 2023."

Appendix 6: The control arithmetic task for young and older adults (Exp. 1)

Arithmetic task

"We now want you to solve a calculation task. Please count aloud backwards from 200 by 2. Do not rush, you are not being timed or evaluated. Do you have any questions?" "Begin"

If they finish before the 5 minutes then ask them to start the task over (back from 200)

200	160	120	80	40
198	158	118	78	38
196	156	116	76	36
194	154	114	74	34
192	152	112	72	32
190	150	110	70	30
188	148	108	68	28
186	146	106	66	26
184	144	104	64	24
182	142	102	62	22
180	140	100	60	20
178	138	98	58	18
176	136	96	56	16
174	134	94	54	14
172	132	92	52	12
170	130	90	50	10
168	128	88	48	8
166	126	86	46	6
164	124	84	44	4
162	122	82	42	2

Appendix 7: The consent form (Exp. 1)

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS
CONSENT TO PARTICIPATE IN RESEARCH
Factors affecting executive functioning in older adults

Supervising Investigator: Dr. Lixia Yang; Email: lixiay@psych.ryerson.ca
Student researcher: Leen Nasser
Lab: Cognitive Aging Laboratory.
Lab Phone: (416) 979-5000 ext. 4987

You are being invited to participate in a research study, which is the second and final part of the student researcher's Master's Thesis. Please read this Consent Form so that you understand what your participation will involve. Before you consent to participate, please ask any questions necessary to be sure you understand what your participation will involve.

Investigators: Dr. Lixia Yang (Associate Professor) and Leen Nasser (MA student), Department of Psychology, Ryerson University.

Purpose of the Study: This study examines executive functioning and its associated factors in older adults. We plan to recruit 16 older adults. Executive functioning is the ability to perform a wide variety of cognitive processes such as planning, memory and multitasking. It is a crucial aspect of cognition that is incorporated when engaging in numerous daily life activities.

Description of the Study and Your Participation: Tasks involved in this study measure affective (e.g., mood) and physiological state (e.g., biological and physiological functioning), along with executive functioning. The whole procedure will take approximately 1.5-2 hours, including the following components: (1) some written questionnaires and self-report scales, including questions that ask for information such as age, gender, and past and current health status. This information is requested in order to evaluate whether any of the listed factors could influence your task performance; (2) collection of saliva samples, as an assessment of biological status across time, on six separate occasions throughout the procedure;(3) collection of physiological responses with specific instruments, including a pulse plethysmogram (PPG) instrument that will be attached to your left index finger; (4) a communications task that requires you to prepare and then convey some information on a designated topic; (5) a mental arithmetic task that requires you to complete a set of math questions; (6) some computerized cognitive tasks; and (7) a short video clip. The study takes place at the Psychology Research and Training Centre of Ryerson University (105 Bond St.). Individual research findings will not be available for distribution; however, group results can be requested by participants and will be provided by mail or email.

Potential Risks and Discomforts: The potential risks associated with participation are minimal. Risks, if any, are psychological and physiological in nature. The major tasks utilized are well validated and are widely used techniques that have no known reports of unfavorable effects in the long term. However, the tasks may be challenging and have the potential to cause some subjective feelings of discomfort. Participants may experience potential physical discomfort associated with being attached to the physiological testing instruments. However, these potential feelings of discomfort are not markedly worse than what would be experienced routinely in everyday circumstances. In addition, we anticipate that these feelings are temporary and will not last beyond the completion of the current study. If you do experience too much discomfort or distress while engaged in the study, you have the right to (1) decline to answer any question or completing a task, and (2) to withdraw your participation at any given point during the experiment.

Potential Benefits to Participants and/or to Society: As a result of your participation in this study, you will have the benefit of contributing to and learning about psychological research. Although you personally

might not receive any direct benefit from participation in this study, results and overall findings from this research can potentially provide you with related knowledge that can be possibly applied and directly related to how you function throughout daily life.

Payment for Participation: You will be compensated $20 for your time of participation, regardless of whether you complete the entire study or withdraw at any time point during the procedure.

Confidentiality: In accordance with the Personal Health Information Protection Act, any health information will be collected, used, stored and shared in a manner that protects the confidentiality and privacy of individuals. We will take great care to protect your confidentiality and privacy. E-Data will be coded with participant numbers and saved in a password-protected external hard-drive. Saliva sample will be coded/labeled with participant numbers and project name and saved for data analysis and validation purpose in a secure research-specific fridge at the Stress Institute of Ryerson University and will be permanently shredded when no longer required (10 years after publication). Any information learned about you during this study will be kept confidential, and neither your name nor any other identifying information will be made available to anyone other than the investigators. The physical copies of documents involving this information (e.g., consent form) will be secured in a locked filing cabinet in the lab and will be shredded when no longer required (10 years after the publication). In any reports, publications or presentation, no individual will be identified, and only group results will be presented.

Data Dissemination: The data will be coded with identification numbers that are not related to, and cannot be traced back to, the participants from whom the data has been collected. The data will be saved on lab computers that have multiple layers of password protection and encryption. The lab computers are in a locked lab room at all times. The data will then be analyzed and will potentially be presented at psychological science conferences across Canada, as well as potentially published in academic journals.

Voluntary Participation and Withdrawal: Participation in this study is voluntary in nature. Your decision on whether or not to participate has no bearing on your past, present or future relationship with Ryerson University. You may withdraw from the study at any time or refuse to answer particular questions, or part of any questionnaires or tests without any penalty.

Questions about the Study: If you have any questions about the research now, please ask the experimenter. If you have questions about the research later, please contact Dr. Lixia Yang at (416) 979-5000 (ext.6522) or email lixiay@psych.ryerson.ca. If you have questions regarding your rights as a human participant in this study, you may contact the Ryerson University Research Ethics Board: rebchair@ryerson.ca, Ryerson University, 350 Victoria Street, Toronto, Ontario, M5B 2K3, (416) 979-5042.

Signature of Research Participant/Legal Representative: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study as described within this document, and that all of your questions have been answered appropriately. Your signature also indicates that you agree to participate in this study and have been explained that you have the option to change your mind and withdraw your consent to participate at any time. Signing this also indicates that you have been given a copy of this agreement. Finally, it has been explained to you that by signing this consent agreement you are not giving up any of your legal rights. By signing below, I acknowledge that I have read and understood all of the above statements and agree to voluntarily participate in this study.

_____	_____	_____
Name of the Participant (please print)	Signature of the Participant	Date

_____	_____
Signature of Investigator	Date

Appendix 8: Post debrief data use consent form (Exp. 1)

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

CONSENT TO PARTICIPATE IN RESEARCH-II
Factors affecting executive functioning in older adults

Supervising Investigator: Dr. Lixia Yang; Email: lixiay@psych.ryerson.ca
Student researcher: Leen Nasser
Lab: Cognitive Aging Laboratory.
Lab Phone: (416) 979-5000 ext. 4987

Please read this Consent Form which clarifies the deceptive component which was incorporated into the study. Before you consent to have your data disseminated, please ask any questions necessary to be sure you understand what the data collected will be used for.

Investigators: Dr. Lixia Yang (Associate Professor) and Leen Nasser (MA student), Department of Psychology, Ryerson University.

Purpose of the Study: This study examines the **effects of acute psychosocial stress** on executive functioning and its associated factors in older adults. We plan to recruit 16 older adults. Executive functioning is the ability to perform a wide variety of cognitive processes such as planning, memory and multitasking. It is a crucial aspect of cognition that is incorporated when engaging in numerous daily life activities. Acute psychosocial stress has been depicted to have a negative impact on executive functions in younger adults. The purpose of this study is to investigate the impact of acute stress on executive functions specifically among older adults.

Deceptive component of the study: In order to induce genuine stress in our participants, we were unable to disclose the information that you will undergo a task that is specifically intended to increase your stress levels. By asking you to prepare for a five minute speech on social media, to deliver a five minute speech on social media, and count aloud backwards from 2023 by 17, our purpose was to elevate your stress levels, so we can examine the effect of stress on your performance on the executive functioning scores which you underwent after the stress phase. Further the individual who came into the room was not a 'behavioural analyst', they were a Research Assistant in our lab, who attended the stress portion of the study to further elevate your stress levels. The audio and video recorders were turned off at all times of the study, we do not have any video or audio data collected. We displayed these devices in the room and falsely informed you that you were being video and audio recorded to further elevate your stress levels. Our stress induction technique is adapted from the Trier Social Stress Test (TSST; Kirschbaum & Hellhammer, 1993), a well cited and robust method used to induce acute levels of psychosocial stress in lab settings. Its effect is temporary and does not have any long term effects on those who undergo this test.

Potential Discomfort: We apologize for any discomfort that you may have experienced during the stress task. We were unable from informing you of this discomfort beforehand as the only way to ensure the success of experiencing stress is for the participant to not be aware that they should feel stressed.

Data Dissemination: The data will be coded with identification numbers that are not related to, and cannot be traced back to, the participants from whom the data has been collected. The data will then be analyzed

and will potentially be presented at psychological science conferences across Canada, as well as potentially published in academic journals.

Questions about the Study: If you have any questions about the research now, please ask the experimenter. If you have questions about the research later, please contact Dr. Lixia Yang at (416) 979-5000 (ext.6522) or email lixiay@psych.ryerson.ca. If you have questions regarding your rights as a human participant in this study, you may contact the Ryerson University Research Ethics Board: rebchair@ryerson.ca, Ryerson University, 350 Victoria Street, Toronto, Ontario, M5B 2K3, (416) 979-5042.

Signature of Research Participant/Legal Representative: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study as described within this document, and that all of your questions have been answered appropriately. Your signature also indicates that you agree to have the researcher analyse the data collected and publish findings using this data. Signing this also indicates that you have been given a copy of this agreement. Finally, it has been explained to you that by signing this consent agreement you are not giving up any of your legal rights. By signing below, I acknowledge that I have read and understood all of the above statements and agree to have my data anonymously used for research purposes.

_____	_____	_____
Name of the Participant (please print)	Signature of the Participant	Date

_____	_____
Signature of Investigator	Date

Appendix 9: The consent form for young adults (Exp. 2)

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

CONSENT TO PARTICIPATE IN RESEARCH
Factors affecting executive functioning in young and older adults

Principal Investigator: Dr. Lixia Yang; Email: lixiay@psych.ryerson.ca
Researchers: Leen Nasser; Email: lnasser@psych.ryerson.ca
Linda Truong; Email: ltruong@psych.ryerson.ca
and Leonithas Meridis; Email: leonithas.meridis@ryerson.ca
Lab: Cognitive Aging Laboratory.
Lab Phone: (416) 979-5000 ext. 4987

You are being invited to participate in a research study. Please read this Consent Form so that you understand what your participation will involve. Before you consent to participate, please ask any questions necessary to be sure you understand what your participation will involve.

Investigators: Dr. Lixia Yang (Associate Professor) and Linda Truong (PhD Research Associate), Department of Psychology, Ryerson University.
Purpose of the Study: This study examines executive functioning and its associated factors in young and older adults. Executive functioning is the ability to perform a wide variety of cognitive processes such as planning, memory and multitasking. It is a crucial aspect of cognition that is incorporated when engaging in numerous daily life activities. For this study, we plan to recruit 40 young and 40 older adults. The younger adult participants will be students enrolled in the Introduction to Psychology (PSY 102 / 202) courses.
Description of the Study and Your Participation: Tasks involved in this study measure affective (e.g., mood) and physiological state (e.g., biological and physiological functioning), along with executive functioning. The whole procedure will take approximately 2 hours, including the following components: (1) some written questionnaires and self-report scales, including questions that ask for information such as age, gender, and past and current health status. This information is requested in order to evaluate whether any of the listed factors could influence your task performance; (2) collection of saliva samples, as an assessment of biological status across time, on 5 separate occasions throughout the procedure;(3) collection of physiological responses with specific instruments, including a pulse plethysmogram (PPG) instrument that will be attached to your left index finger; (4) a communications task that requires you to prepare and then convey some information on a designated topic; (5) a mental arithmetic task that requires you to complete a set of math questions; (6) some computerized cognitive tasks; and (7) a short video clip. The study takes place at the Psychology Research and Training Centre of Ryerson University (105 Bond St.). Individual research findings will not be available for distribution; however, group results can be requested by participants and will be provided by mail or email.
Potential Risks and Discomforts: The potential risks associated with participation are minimal. Risks, if any, are psychological and physiological in nature. The major tasks utilized are well validated and are widely used techniques that have no known reports of unfavorable effects in the long term. However, the tasks may be challenging and have the potential to cause some subjective feelings of discomfort. Participants may experience potential physical discomfort associated with being attached to the physiological testing instruments. However, these potential feelings of discomfort are not markedly worse than what would be experienced routinely in everyday circumstances. In addition, we anticipate that these feelings are temporary and will not last beyond the completion of the current study. If you do experience too much discomfort or distress while engaged in the study, you have the right to (1) decline to answer

any question or completing a task, and (2) to withdraw your participation at any given point during the experiment.

Potential Benefits to Participants and/or to Society: As a result of your participation in this study, you will have the benefit of contributing to and learning about psychological research. Although you personally might not receive any direct benefit from participation in this study, results and overall findings from this research can potentially provide you with related knowledge that can be possibly applied and directly related to how you function throughout daily life.

Incentives for Participation: You will be granted 2 credits for your time of participation, regardless of whether you complete the entire study or withdraw at any time point during the procedure.

Confidentiality: In accordance with the Personal Health Information Protection Act, any health information will be collected, used, stored and shared in a manner that protects the confidentiality and privacy of individuals. We will take great care to protect your confidentiality and privacy. E-Data will be coded with participant numbers and saved in a password-protected external hard-drive. Saliva sample will be coded/labeled with participant numbers and project name and saved for data analysis and validation purpose in a secure research-specific fridge at the Stress Institute of Ryerson University and will be permanently shredded when no longer required (10 years after publication). Any information learned about you during this study will be kept confidential, and neither your name nor any other identifying information will be made available to anyone other than the investigators. The physical copies of documents involving this information (e.g., consent form) will be secured in a locked filing cabinet in the lab and will be shredded when no longer required (10 years after the publication). In any reports, publications or presentation, no individual will be identified, and only group results will be presented.

Voluntary Participation and Withdrawal: Participation in this study is voluntary in nature. Your decision on whether or not to participate has no bearing on your past, present or future relationship with Ryerson University. You may withdraw from the study at any time or refuse to answer particular questions, or part of any questionnaires or tests without any penalty. If you withdraw from this study at any point, you will still be granted the 2 credits.

Questions about the Study: If you have any questions about the research now, please ask the experimenter. If you have questions about the research later, please contact Dr. Lixia Yang at (416) 979-5000 (ext.6522) or email lixiay@psych.ryerson.ca. If you have questions regarding your rights as a human participant in this study, you may contact the chair of Ryerson University Research Ethics Board at (416) 979 5000 (ext. 4791) or email rebchair@ryerson.ca.

Signature of Research Participant/Legal Representative: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study as described within this document, and that all of your questions have been answered appropriately. Your signature also indicates that you agree to participate in this study and have been explained that you have the option to change your mind and withdraw your consent to participate at any time. Signing this also indicates that you have been given a copy of this agreement. Finally, it has been explained to you that by signing this consent agreement you are not giving up any of your legal rights. By signing below, I acknowledge that I have read and understood all of the above statements and agree to voluntarily participate in this study.

_____	_____	_____
Name of the Participant (please print)	Signature of the Participant	Date

_____	_____
Signature of Investigator	Date

Appendix 10: The consent form for older adults (Exp. 2)

DEPARTMENT OF PSYCHOLOGY
FACULTY OF ARTS

CONSENT TO PARTICIPATE IN RESEARCH
Factors affecting executive functioning in young and older adults

Principal Investigator: Dr. Lixia Yang; Email: lixiay@psych.ryerson.ca
Student researchers: Leen Nasser, Linda Truong and Leonithas Meridis
Lab: Cognitive Aging Laboratory.
Lab Phone: (416) 979-5000 ext. 4987

You are being invited to participate in a research study. Please read this Consent Form so that you understand what your participation will involve. Before you consent to participate, please ask any questions necessary to be sure you understand what your participation will involve.

Investigators: Dr. Lixia Yang (Associate Professor) and Leen Nasser (MA student), Department of Psychology, Ryerson University.

Purpose of the Study: This study examines executive functioning and its associated factors in young and older adults. We plan to recruit 40 young and 40 older adults. Executive functioning is the ability to perform a wide variety of cognitive processes such as planning, memory and multitasking. It is a crucial aspect of cognition that is incorporated when engaging in numerous daily life activities. .

Description of the Study and Your Participation: Tasks involved in this study measure affective (e.g., mood) and physiological state (e.g., biological and physiological functioning), along with executive functioning. The whole procedure will take approximately 1.5-2 hours, including the following components: (1) some written questionnaires and self-report scales, including questions that ask for information such as age, gender, and past and current health status. This information is requested in order to evaluate whether any of the listed factors could influence your task performance; (2) collection of saliva samples, as an assessment of biological status across time, on 5 separate occasions throughout the procedure;(3) collection of physiological responses with specific instruments, including a pulse plethysmogram (PPG) instrument that will be attached to your left index finger*;* (4) a communications task that requires you to prepare and then convey some information on a designated topic; (5) a mental arithmetic task that requires you to complete a set of math questions; (6) some computerized cognitive tasks; and (7) a short video clip. The study takes place at the Psychology Research and Training Centre of Ryerson University (105 Bond St.). Individual research findings will not be available for distribution; however, group results can be requested by participants and will be provided by mail or email.

Potential Risks and Discomforts: The potential risks associated with participation are minimal. Risks, if any, are psychological and physiological in nature. The major tasks utilized are well validated and are widely used techniques that have no known reports of unfavorable effects in the long term. However, the tasks may be challenging and have the potential to cause some subjective feelings of discomfort. Participants may experience potential physical discomfort associated with being attached to the physiological testing instruments. However, these potential feelings of discomfort are not markedly worse than what would be experienced routinely in everyday circumstances. In addition, we anticipate that these feelings are temporary and will not last beyond the completion of the current study. If you do experience too much discomfort or distress while engaged in the study, you have the right to (1) decline to answer any question or completing a task, and (2) to withdraw your participation at any given point during the experiment.

Potential Benefits to Participants and/or to Society: As a result of your participation in this study, you

will have the benefit of contributing to and learning about psychological research. Although you personally might not receive any direct benefit from participation in this study, results and overall findings from this research can potentially provide you with related knowledge that can be possibly applied and directly related to how you function throughout daily life.

Payment for Participation: You will be compensated $20 for your time of participation, regardless of whether you complete the entire study or withdraw at any time point during the procedure.

Confidentiality: In accordance with the Personal Health Information Protection Act, any health information will be collected, used, stored and shared in a manner that protects the confidentiality and privacy of individuals. We will take great care to protect your confidentiality and privacy. E-Data will be coded with participant numbers and saved in a password-protected external hard-drive. Saliva sample will be coded/labeled with participant numbers and project name and saved for data analysis and validation purpose in a secure research-specific fridge at the Stress Institute of Ryerson University and will be permanently shredded when no longer required (10 years after publication). Any information learned about you during this study will be kept confidential, and neither your name nor any other identifying information will be made available to anyone other than the investigators. The physical copies of documents involving this information (e.g., consent form) will be secured in a locked filing cabinet in the lab and will be shredded when no longer required (10 years after the publication). In any reports, publications or presentation, no individual will be identified, and only group results will be presented.

Voluntary Participation and Withdrawal: Participation in this study is voluntary in nature. Your decision on whether or not to participate has no bearing on your past, present or future relationship with Ryerson University. You may withdraw from the study at any time or refuse to answer particular questions, or part of any questionnaires or tests without any penalty.

Questions about the Study: If you have any questions about the research now, please ask the experimenter. If you have questions about the research later, please contact Dr. Lixia Yang at (416) 979-5000 (ext.6522) or email lixiay@psych.ryerson.ca. If you have questions regarding your rights as a human participant in this study, you may contact the Ryerson University Research Ethics Board: Toni Fletcher (REB Coordinator) at toni.fletcher@ryerson.ca. c/o Office of the Associate Vice President, Research & Innovation, Ryerson University, 350 Victoria Street, Toronto, Ontario, M5B 2K3, (416) 979-5042.

Signature of Research Participant/Legal Representative: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study as described within this document, and that all of your questions have been answered appropriately. Your signature also indicates that you agree to participate in this study and have been explained that you have the option to change your mind and withdraw your consent to participate at any time. Signing this also indicates that you have been given a copy of this agreement. Finally, it has been explained to you that by signing this consent agreement you are not giving up any of your legal rights. By signing below, I acknowledge that I have read and understood all of the above statements and agree to voluntarily participate in this study.

_____	_____	_____
Name of the Participant (please print)	Signature of the Participant	Date

_____	_____
Signature of Investigator	Date

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