TESTING THE IMPACT OF FLOW-BASED, MODERATE-INTENSITY YOGA ON EXECUTIVE FUNCTIONING AND STRESS AMONG LOW ACTIVE WORKING ADULTS WITH SYMPTOMS OF STRESS

BY

MADHURA ABHAY PHANSIKAR

DISSERTATION

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Doctoral Committee:

Associate Professor Sean Mullen, Chair
Associate Professor Neha Gothe
Associate Professor Rosalba Hernandez
Associate Professor Sandraluz Lara-Cinisomo

ABSTRACT

In the past decade, research on effects of yoga on cognitive functioning has increased, but most studies have investigated the impact of low-intensity yoga postures. There is growing consensus among researchers regarding the need for exploring the effects of different styles of yoga. However, there is no evidence whether flow-based, moderate-intensity forms of yoga can deliver cognitive and psychosocial benefits. The purpose of the study was to assess the feasibility and efficacy of an eight-week, moderate-intensity, flow-based yoga intervention, on cognitive functioning and psychosocial stress, as compared to a waitlist control group. The sample was full-time working adults with symptoms of stress. The intervention included postures and movements, followed by breathing and relaxation, and was conducted 3 times/week for ~50 minutes. It was titrated in terms of supervision, starting with individual and group sessions taught by a certified instructor on Zoom, and ending with self-guided sessions. Attendance for the self-guided sessions was assessed using Fitbit and post-sessions logs. Overall attendance was 75.1%. Results showed an improvement in working memory with the yoga group had higher accuracy as compared to the control group (*M*s±*SD* = 7.30±3.05 vs. 6.11±2.70). There was a reduction in stress and anxiety (*M*s±*SD* = 34.97±10.34 vs. 39.36±11.96) in the yoga group as compared to the control group. Reduction in stress from baseline to week four mediated the improvement in working memory. Additionally, there was an improvement in yoga self-efficacy ($\eta_p^2 = 0.059$), self-regulation ($\eta_p^2 = 0.066$), positive psychological well-being, and physical activity frequency ($\eta_p^2 = 0.076$), as compared to the control group. Participants enjoyed the intervention (100%) and liked to learn through video guided instruction (95%). Overall, this study is one of the first studies to show that regular moderate-intensity flow-based yoga may improve cognitive functioning. The yoga intervention decreased stress and anxiety, and improved well-being. This further augment the growing evidence of cognitive and psychosocial benefits of yoga among working adults with stress and low physical activity. The mediation analysis provides evidence for the hypothesized stress reduction mechanism underlying cognitive change. The results suggest that it is feasible to learn yoga through video instructions, and has implications for designing more video-guided yoga studies, and encouraging self-guided practice, to increase accessibility to yoga for different populations. This results provide support for the role of Social Cognitive Theory in impacting behavior change techniques related to physical activity, and provide support for a gradually titrated intervention in terms of supervision. This is one of the few studies to add to the literature that yoga improves aspects of positive psychological well-being. More research is needed to extend and replicate these findings across larger and varied samples. Future studies should examine the efficacy in comparison with other physical and mind-body activities, to investigate the unique impact of moderate-intensity flow-based yoga. Future studies should focus on aspects such as exploring more mechanisms underlying cognitive and stress change, implement more behavior change techniques for sustained engagement in the intervention, and tailor technology based on accessibility for different populations.

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CHAPTER I: INTRODUCTION

Background and significance

Mental health conditions are now the leading cause of disability in the developed countries. Psychosocial stress has increased over the years and is a global problem among full time employees (Seňová & Antošová, 2014). For example, in a sample of full-time working adults from 45 Dutch companies, 23% reported having psychological distress, and 22% reported having fatigue (Bültmann, Kant, Kasl, Beurskens, & Van Den Brandt, 2002). In some populations such as primary healthcare workers, the prevalence was higher, with 59% reporting stress symptoms (Wiegner, Hange, Björkelund, & Ahlborg, 2015). Other studies have reported a prevalence of perceived stress or anxiety among 35% (Holmgren, Dahlin-Ivanoff, Björkelund, & Hensing, 2009) or 10% of employees, especially among middle-aged women (Andrea et al., 2004; Bergdahl & Bergdahl, 2002). Stress is often comorbid with depression and/or anxiety (Bergdahl & Bergdahl, 2002; Hanel et al., 2009), and rates of depression and anxiety have increased over the years in the US (Weinberger et al., 2018).

In European countries and the UK, stress-related illness is one of the main reasons for increased sick leave (Henderson, Glozier, & Elliott, 2005; *Mental health: facing the challenges, building solutions*, 2005; Suff, 2019), and has been described as an epidemic (*Mental health: facing the challenges, building solutions*, 2005). According to the National Institute of Occupational Safety and Health, similar statistics are observed in the US. In 1999, between 26% to 40% of American employees report moderate to severe stress due to work (Sauter et al., 1999). According to the global poll conducted by Gallop in 2018, more than half of the adults surveyed reported facing stress, and stress levels were higher in the American workforce as compared to 143 countries across the globe (*Gallup 2019 global emotions report*, n.d.). It has also escalated progressively over the last three decades, among employees (“Workplace Stress Continues to Mount,” 2018), along with an increase in stress-related sick leave/absence (“Workplace stress - The American Institute of Stress,” n.d.). Stress levels were the highest among middle aged adults, followed by young adults. Stress also has an economic burden in terms of healthcare costs. Additionally, it contributes to the economic burden in terms of days lost in productivity due to sickness (Henderson et al., 2005). Unanticipated absence due to stress is estimated to cost employers anywhere from $605 per worker/year to $3.5 million annually (“Workplace stress - The American Institute of Stress,” n.d.), and costs about $190 billion in healthcare (Goh, Pfeffer, & Zenios, 2016).

Psychological distress is associated with an increased likelihood of physical and mental diseases, including but not limited to headaches, flu, obesity, cardiovascular disease (CVD), human immunodeficiency virus, cancer, and depression (Blanc-Lapierre, Rousseau, & Parent, 2017; Block, He, Zaslavsky, Ding, & Ayanian, 2009; Chida, Hamer, Wardle, & Steptoe, 2008; Chrousos, 2000; Sheldon Cohen, Janicki-Deverts, & Miller, 2007; DeLongis, Folkman, & Lazarus, 1988; Epel, 2009; Garg et al., 2001; Gouin & Kiecolt-Glaser, 2011; J. Wang et al., 2005). It is also shown to lower immunity, which too, increases the likelihood of contracting diseases (Ho, Fang Neo, Chua, Cheak, & Mak, 2010).

Exposure to stress leads to the activation of the sympathetic nervous system (SNS) and suppression of the parasympathetic nervous system (PNS), along with the release of adrenaline and non-adrenaline to cope with the stressor. Another system that gradually reacts to stress is the hypothalamus-pituitary-adrenal axis. When stress is encountered, the hypothalamus secretes a hormone known as the corticotropin releasing hormone. This hormone stimulates the release of adrenocorticotropic hormone (ACTH) from the pituitary glands. ACTH in turn, stimulates the release of glucocorticoid hormones (i.e. cortisol in humans) as a way of preparing the mind and the body to respond to the stressor by increasing energy levels. The body reacts in a similar manner whether one is experiencing physical or psychological stress (De Kloet, Joëls, & Holsboer, 2005; Sapolsky, Krey, & McEwen, 1986).

The presence of cortisol in a higher level as compared to usual, due to chronic stress, is detrimental to the body and the brain. A high level of cortisol is associated with obesity and a detrimental effect on metabolic factors (Rosmond, Dallman, & Björntorp, 1998), an increase in cardiovascular risk factors (Vogelzangs et al., 2010), as well as cognitive aspects. It has been shown to impair long term potentiation in the hippocampus thus impairing memory formation, facilitate long term depression, and is related to a number of psychiatric disorders (J. J. Kim & Diamond, 2002). High levels of cortisol have also been found in patients with Alzheimer's disease (K. L. Davis et al., 1986; Weiner, Vobach, Olsson, Svetlik, & Risser, 1997), and a high level of stress is detrimental to the pathology of many mental health disorders such as Alzheimer's disease, multiple sclerosis, and depression (Esch, Stefano, Fricchione, & Benson, 2002). Apart from this, patients having a high level of cortisol, such as those with Cushing's disease and depression, showed structural and functional brain impairments, and poorer performance on attention and memory tasks (Wolf, 2003). In another study, older adults collected their cortisol samples and underwent cognitive assessments annually for a period of three years. Results showed that a higher level of cortisol was associated with poorer declarative memory and executive functioning assessed via the Stroop task and trail making task (Li et al., 2006).

Cortisol can cross the blood brain barrier, which is a border of cells that prevents pathogens from the blood circulating in the body to cross over to the central nervous system.

Prolonged stress also increases the amount of glucocorticoid receptors in the brain, leading to more uptake of cortisol. These are found in a number of areas that are implicated in cognitive functioning, such as the hippocampus, dentate gyrus, amygdala (De Kloet et al., 2005), and prefrontal cortex (Wolf, 2003). Wolf (2003) reviewed the research on HPA axis and cognitive functioning, specifically memory. Overall, results suggested the presence of an inverted U relationship between cortisol and cognitive functioning, with a high level of cortisol being detrimental to cognitive functioning, such as a reduction in neuronal excitability and impairment of synaptic plasticity, and impaired performance on tasks of working memory and delayed recall. Other studies have also shown impairments in memory and hippocampal functioning to be associated with elevated cortisol levels (Lupien et al., 1998).

Lupien et al (2009) conducted a review about the effects of stress on brain and cognition, across the lifespan from pre-natal stress to stress during aging. Stress among adults was associated with memory impairment, reduced hippocampal volume, reduced frontal lobe volume, and had an inverted-U relationship with axonal transport in neurons in the prefrontal cortex. Similarly, McEwen and colleagues (2012) also provided evidence that acute and chronic stress can cause structural and functional changes in the prefrontal cortex and amygdala, and affect hippocampal dependent cognitive functioning. This suggests that chronic stress may have a role in the survival and function of neurons in the prefrontal cortex, which plays a key role in executive functioning.

Complementary and alternative medicine (CAM) use is popular for stress reduction among those with a moderate level of mental distress. Among adults reporting mental distress, 40% reported using CAM, with 10% of those engaging in yoga, in a nationally representative survey conducted in 2012 (Rhee, Evans, McAlpine, & Johnson, 2017). Yoga, commonly pronounced as Yogā, means 'union,' and is one of the limbs in the eight limb process advocated by the Indian sage Patanjali, which include yama (abstinences), niyama (observances), asana (yoga postures), pranayama (breath control), pratyahara (withdrawal of the senses), dharana (concentration), dhyana (meditation) and samadhi (absorption). Traditionally, yoga was considered as a method for preparing the body and mind for the next steps or limbs of the eight-limb process, but now it is considered as a mindful physical activity. Yoga interventions and classes in the West mostly focus on three of the eight limbs, namely, yoga postures, breathing exercises and meditation. Hatha Yoga is the most popular form of yoga practiced in America (Morone & Greco, 2007). Hatha yoga is an umbrella term that includes different styles of yoga that vary in their speed, difficulty of postures, or the type of movement, among other aspects (Morone & Greco, 2007).

The prevalence of yoga is growing over the years among adults in Western societies, where it is often perceived as a complementary form of exercise. According to a nationally representative survey of US adults in 2007, 6.1% had engaged in yoga in the past 12 months (Barnes, Bloom, & Nahin, 2008). In 2012, that number increased to 8.9%, which is roughly 21 million (Cramer, Ward, et al., 2016) and the lifetime prevalence of yoga was 13.2% (31 million). In 2017, 14.5% of the population reported engaging in Yoga, Tai-Chi or Qigong in the last 12 months (C. Wang, Li, Choudhury, & Gaylord, 2019). Cramer et al (2016) reported that adults who had engaged in yoga in the last 12 months were more likely to be young (18-29 years of age) females (73.7%). The most common reason for practicing yoga included wellness or disease prevention (78.4%) of which 6.4% practiced it specifically for stress reduction, and other reasons included improving their energy (66.1%) or immune function (49.7%). Other studies have also reported that reasons for engaging in yoga included managing mental health problems like depression, anxiety, stress, and insomnia (Pilkington, Kirkwood, Rampes, & Richardson, 2005; C. Wang et al., 2019). The most common source of yoga information seemed to be yoga classes, with 51.2% having attended yoga classes, followed by DVDs or CDs (36.5%), the internet (26.9%) and print media (24.3%) (Cramer, Ward, et al., 2016). A majority of respondents primarily reported stress reduction as an outcome of their yoga practice (84.7%), followed by improved overall health (81.0%), improved emotional well-being (67.5%), improved sleep (59.1%), and increased sense of control over their health (56.9%). There are a number of online yoga videos, classes, and podcasts (Muntean, Neustaedter, & Hennessy, 2015), and over 120 mobile applications (Cummiskey, 2011; García-Holgado, Reiris, Kearney, Martinus, & García-Peñalvo, 2019; S. A. Smith et al., 2016; Thirumalai et al., 2018).

According to report by the *International Health, Racquet & Sportsclub Association* (IHRSA), participation in yoga has increased by 8% from 2015 to 2019. In 2018, more than one out of five health club members participated in yoga programs in the US, making it the most preferred group activity that year (Rodriguez, 2019). As evidenced by two studies reporting on prevalence of yoga, yoga has continued to be most popular among young adults aged 18-34 years, evident (Cramer, Ward, et al., 2016; Rodriguez, 2019). IHRSA has recommended that shorter sessions, lasting 20 to 30 minutes, may be most appropriate for this age group to accommodate their busy schedules.

In the past decade, research on effects of yoga on cognitive functioning among relatively healthy adults, has increased. In two reviews covering more than 15 studies, both acute and chronic yoga studies showed a positive association of yoga with aspects of executive functioning (Gothe & McAuley, 2015; Luu & Hall, 2016). Gothe and McAuley (2015) found that the strongest effects were seen on tasks of attention and processing speed, followed by executive functioning, and memory. Most of these studies focused on Hatha or Iyengar yoga, across the lifespan. Both the reviews highlighted the need for more RCTs, with larger sample sizes, in order to draw firm conclusions about the cognitive benefit of yoga.

Yoga research conducted so far has primarily investigated low intensity yoga sessions focused on Hatha yoga, lasting an average of 60 minutes. There is growing consensus among researchers regarding the need for exploring the effects of different styles of yoga (Cowen & Adams, 2007; Larkey, Jahnke, Etnier, & Gonzalez, 2009; Riley & Park, 2015; Ross & Thomas, 2010). Recently, Schmalzl et al (2015) highlighted that few studies examine the contribution of the individual components of yoga, and that "investigations in which type, amount or intensity of either movement, breath or attention are carefully manipulated, while the other components are kept constant, will be particularly informative in this regard." In a systematic review comparing the effects shown by different types of yoga, the maximum amount of studies were on Hatha yoga and Iyengar yoga (Cramer, Lauche, Langhorst, & Dobos, 2016). It has been found that the physical and physiological effects of yoga can differ by style. In an RCT comparing Hatha yoga to Ashtanga yoga among young adults, both groups improved in trunk strength, and flexibility, but Ashtanga group improved in perceived stress and diastolic blood pressure as well (Cowen & Adams, 2005). Hatha yoga elicited a percent maximum heart rate of 45% whereas Ashtanga yoga was 54%. Cowen and Adams (2005) reported that there has not been enough research comparing the different styles of yoga.

Other schools of Yoga beyond Hatha yoga have gained popularity, including Ashtanga yoga, Vinyasa yoga (VY) and/or power yoga. While it can be debated that these forms of yoga may or may not fall under the umbrella term of Hatha yoga, there are some key differences between them and Hatha Yoga as researched until now. Vinyasa yoga or Ashtanga yoga or power yoga or sun salutation sequences (found in hatha, Vinyasa and Ashtanga yoga) are all more intense, almost fitness-based forms of yoga. In these, the focus is on flow and transitions between the movements rather than holding the poses, is usually fast paced, and uses large body movements while following a specific breathing pattern. Breathing is synchronized with the movement throughout the sequence. The practice of these moderate intensity forms of yoga is common among yoga practitioners. In a survey of 1045 yoga practitioners in the US, 85.8% reported doing sun salutation or other vigorous forms of yoga, including arm balances or backbends, during their regular yoga practice (Ross, Friedmann, Bevans, & Thomas, 2013). These forms of yoga have been studied for various reasons. It is hypothesized that an activity that combines moderate intensity exercise along with breathing, both of which have shown beneficial effects separately, may be beneficial to patients with depression (Uebelacker et al., 2010).

There is growing evidence that moderate intensity styles of yoga involve more cardiovascular activity than low intensity hatha yoga. Among regular yoga practitioners, performing a 60-minute Vinyasa sequence yielded an average heart rate of 109 beats per minute, a high rating of perceived exertion, and an average of 273 kcals (i.e. 3.6 MET), which was lower than that observed during treadmill walking (353.8 kcals) (S. A. Sherman et al., 2017). In another study, average heart rate was reported to be 107 bpm and the activity was between 50-63% of max heart rate for most participants (Shepperson Ward, McCluney, Bosch, & Bosch, 2013). Other studies have reported heart rates between 60-70% of heart rate max (Blank, Raman, Chock, & Krieger, 2001; Hagins, Moore, & Rundle, 2007; Spilde, Porcari, Greany, Doberstein, & Foster, 2005). Ray, Pathak, and Tomer (2011) found that the maximal heart rate during/after a Hatha yoga session was lower than 60%. By comparison, this is higher/lower than Vinyasa yoga and the ACSM recommendation. The energy expenditure in VY is reported to be 2.6 MET (Hagins et al., 2007) or between 3 and 4 MET in a 60 minute session (Gordon, 2014; S. A. Sherman et al., 2017), or 6.7 MET in a 15 minute session (Carroll, Blansit, Otto, & Wygand, 2003). Even 15 minutes of Vinyasa yoga may be moderate intensity based on percent heart rate max (McGuirk, 2012). Thus, VY has the potential to be a moderate intensity activity. In most of these studies, participants were yoga practitioners, and the effects among naïve participants may be different due to difference in the level of fitness and practice. Engaging in a moderate intensity or flow-based form of yoga may offer additional health benefits, such as reduced stress and blood pressure (Cowen & Adams, 2005), as compared to low-intensity yoga. Also, practicing VY has been shown to increase HRV (Tay & Baldwin, 2015), quality of life (Céline Martin & Keats, 2014), reduce risk of type 2 diabetes (Yang et al., 2011), reduce depressive symptoms (Uebelacker et al., 2010), and increase positive affect along with a reduction in negative affect (Gaskins, Jennings, Thind, Becker, & Bock, 2014). There is a dearth of studies comparing styles of yoga that differ in intensity. However, there have been studies of aerobic activity of different intensities. In studies comparing moderate and low intensity activity, it has been found that moderate intensity activity may be more beneficial to aspects of executive functioning, as compared to low intensity activity (Kamijo et al., 2004; Lambourne & Tomporowski, 2010; Loprinzi & Kane, 2015; Wohlwend, Olsen, Håberg, & Palmer, 2017), although the evidence is equivocal.

Sun salutation is another form of flow-based moderate intensity yoga sequence. It involves a sequence of ten or twelve postures, done one after the other in quick succession, along with breathing that is synchronized with each movement. For example, inhalation is done in posture one, exhalation is done in posture two, and so on and so forth. It has been described as 'a unique combination of asana, pranayama, and meditation,' and is helpful in building physical and mental strength (Stec, 2014). The sun salutation sequence comes from Hatha yoga, which is suitable to beginners, and is also found in Ashtanga and VY in a slightly altered manner. Among participants new to yoga, engaging in sun salutation for about 30 minutes was a moderate intensity activity, as seen by a MET of >3.0 and heart rate at >55% of the maximum, as compared to the rest of the hatha yoga practice. Similar results have been reported by systematic reviews (Grabara, 2016; Larson-Meyer, 2016), as well as by another study comparing sun salutation and non-sun salutation sequences of hatha yoga, in terms of heart rate, energy expenditure and oxygen consumption (Clay, Lloyd, Walker, Sharp, & Pankey, 2005). In an intervention which was a combination of tai-chi and sun salutation at a moderate intensity, state anxiety decreased post the intervention (Field, Diego, & Hernandez-Reif, 2010). Further, performing sun salutation does not over stress the joints, may be optimal for the osteogenesis (Omkar, Mour, & Das, 2011), is shown to reduce body mass index, body fat, and increase upper body strength (Bhutkar, Bhutkar, Taware, & Surdi, 2011) and decrease body pain. There is only study that has assessed cognitive functioning after engaging in sun salutation, in young adults engaging in sun salutation vs. breathing exercises vs. a combination of both (Goud Kondam, 2017). Participants engaged in 30 minutes of yoga, followed by either sun salutation, breathing exercises, or a combination of both, for the same duration. Results showed that the combined group outperformed the other groups in their performance on a battery of tasks measuring memory, fluency, attention and orientation among other domains. All three groups were better than the no-activity control group. A confounding factor in this study is the engagement in 30 minutes of yoga irrespective of the group assignment, so the effects on cognition cannot be attributed to a particular component of yoga.

A study for identifying essential components of yoga interventions for reducing depression and anxiety, sought the expertise of 18 yoga teachers having experience in the field of mental health. They reached a consensus that 'coordinated flow of breath with movement' was considered important or essential for reducing both anxiety and depression. They also recommended that, for reducing depression, yoga postures be repetitive, dynamic movements involving chest-openers and back bends (rather than holding poses for long), while focusing on breathing, such as sun salutation (de Manincor, Bensoussan, Smith, Fahey, & Bourchier, 2015).

While Hatha yoga remains widely studied among healthy populations, these fitness-based forms of Yoga have not been thoroughly explored in terms of their feasibility, effectiveness, acceptability, and physiological and psychosocial effects, among healthy populations. It may very well be that these forms of Yoga show the same effects as low-intensity Hatha yoga, but considering that aerobic exercise of different intensities has shown different effects, there is reason to examine the effects of moderate-intensity forms of Yoga. While there is evidence for physical health benefits of these different styles of flow-based yoga, few studies have been designed to investigate the effects of such yoga practice on executive functioning. Evidence for physical health benefits of moderate intensity and/or dynamic yoga styles, evidence for cognitive benefits of Hatha yoga, and the evidence of cognitive benefits of moderate intensity physical activity warrants an investigation of whether a shorter, but moderate intensity and dynamic form of yoga, would yield similar benefits to executive functioning. The purpose was to investigate the potential cognitive effects of a moderate intensity yoga program that can be performed for a shorter period of time as compared to previous interventions, in order to be more suitable to full-time working adults with stress who often report having time constraints.

Specific aims and hypotheses

This study is designed to assess the impact of moderate-intensity flow-based yoga on executive functioning, as compared to a waitlist control group. It was hypothesized that participants engaging in the yoga intervention would perform better on tasks of executive functioning and psychosocial measures, as compared to the waitlist control group. The specific aims were:

1. To assess the feasibility of the remotely delivered yoga intervention
2. To study the efficacy of an 8-week, remotely delivered yoga intervention (flow-based movements, breathing, and relaxation) on improving executive functioning among full-time working adults facing symptoms of chronic stress or anxiety, during a pandemic
3. To study the efficacy of an 8-week, remotely delivered yoga intervention on reducing stress and anxiety among full-time working adults facing symptoms of chronic stress or anxiety, during a pandemic, and assessing the unique impact of postures vs. breathing and relaxation on stress outcomes.
4. To test hypothesized mediation effect of stress reduction on executive functioning

This study is designed to improve executive functioning and stress among full time working adults with symptoms of chronic stress, through moderate-intensity flow-based yoga movements, such as sun salutation. This study is novel in that cognitive effects of styles of yoga that involve performing postures in a dynamic flow usually of a moderate intensity have not been investigated yet. In spite of being a dynamic form of yoga, sun salutation is a part of Hatha yoga and involves postures that are suitable for beginners. It was theorized that engaging in an aerobic and mind-body activity may provide participants with more benefits as compared to an aerobic activity alone. A yoga program shorter in length, and that can be technologically delivered at home, may be more feasible to full-time working adults. If successful, this study will advance the current understanding of cognitive effects of yoga interventions. It will provide people with a technologically delivered yoga activity making it easier for individuals to incorporate in their daily lives.

Definition of terms

Hatha yoga. A school of yoga and an umbrella term that includes different styles of yoga that vary in their speed and difficulty of postures. Hatha yoga primarily focuses on maintaining postures in isometric contraction while standing, sitting, or lying down on the back or stomach, coupled with breathing and meditation exercises.

Sun salutation. A sequence in Hatha yoga wherein the focus is on flow and transitions between the movements rather than holding the poses. Sun salutation are usually fast-paced, and involves whole-body movements, synchronized breathing, and follows a sequence of transitional moves.

Aerobic exercise. A type of physical activity consisting of planned, structured, and repetitive bodily movement with the goal of improving or maintaining one or more components of physical fitness requiring oxygenated blood (American College of Sports Medicine, 2013).

Executive functioning. A set of general-purpose control processes that regulate one's thoughts and behaviors, including behavioral regulation, working memory, planning and organizational skills, and self-monitoring (Miyake & Friedman, 2012; Stuss & Alexander, 2000).

CHAPTER II: REVIEW OF LITERATURE

Physical activity among working adults

In the United States, physical inactivity among adults is a major health issue. Only half of the US adults meet the recommended level of aerobic physical activity, and only 23.3% meet the recommended level of aerobic and strength training (National Center for Health Statistics, 2017). Less than 5% of the adults participate in aerobic activity such as walking, for 30 minutes every day (U.S. Department of Health and Human Services, 2017).

There are differences in physical activity participation among different groups of people. For example, minority racial groups have a higher level of physical inactivity than Caucasians ("Adult physical inactivity prevalence maps by race/ethnicity," n.d.). Another group that is susceptible to physical inactivity is young and middle-aged full-time working adults, who have to juggle family and other responsibilities along with work. Full-time working adults spend more than one-third of their day at their workplace (U.S. Department of Health and Human Services, 2017) and a majority of the workforce performs jobs that do not require them to be physically active (Blackwell & Clarke, 2008). Less than 30% of these working adults met any physical activity guideline, including guidelines for aerobic exercise only, strength exercise only, or a combination of both, and 43% did not meet any physical activity guidelines (Blackwell & Clarke, 2008).

The most common barrier to physical activity reported by full-time working adults is lack of time (Booth, Bauman, Owen, & Gore, 1997; Jaffee, Mahle Lutter, Rex, Hawkes, & Bucaccio, 1999; Kruger, Yore, Bauer, & Kohl, 2007; Leininger, Adams, & DeBeliso, 2015; Scott Leicht, Sealey, & Devine, 2013; Tavares & Plotnikoff, 2008). In reality, it may be a lack of perceived time, or a lack of energy (Kruger et al., 2007), as recent research has shown that adults may have an average of five hours of free time every day (Sturm & Cohen, 2019). Apart from this, long working hours (Sonnentag & Jelden, 2009), facing stress at work (Ng & Jeffery, 2003; Payne, Jones, & Harris, 2002; Sonnentag & Jelden, 2009), and being a blue-collar worker (Burton & Turrell, 2000) can negatively affect engagement in leisure time physical activity after work. Another consistent barrier is a lack of resources to engage in physical activity. Only one in five homes have access to a gym, recreation center, or park, within half a mile (U.S. Department of Health and Human Services, 2017). In a review of studies assessing the association between physical activity and environmental attributes, neighborhood characteristics including a lack of accessibility (e.g. local park) and opportunities (e.g. presence of sidewalks) to engage in physical activity were consistently associated with physical inactivity (Humpel, Owen, & Leslie, 2002).

Efficacy of intervention delivery methods

Workplace interventions have been conducted to increase physical activity among full-time employees, but the evidence for their effectiveness is mixed (Abraham & Graham-Rowe, 2009). Dishman et al (1998) did not find a significant effect of worksite physical activity interventions on physical activity levels, attributable to methodological quality of the studies. The review by Proper et al (2003) found evidence that workplace interventions can have a positive effect on physical activity. Further, in order to be successful, workplace interventions may need to address a wide variety of concerns that pose as barriers to workplace physical activity(Graveling, Crawford, Cowie, Amati, & Vohra, 2008; Kruger et al., 2007; Schwetschenau, O'Brien, Cunningham, & Jex, 2008; Tavares & Plotnikoff, 2008).

On the other hand, home-based interventions may be a viable delivery setting for physical activity interventions. Home-based interventions have been shown to be as effective as supervised group-based interventions to increase physical activity, irrespective of physical activity type or frequency, among middle-aged and older adults (Van Der Bij, Laurant, & Wensing, 2002). In the review by Van Der Bij and colleagues (2002), most of the home-based exercises were of a moderate intensity and included aerobic exercise, strength training, or flexibility exercises, with a prescribed dose of 3x/week or more. Adherence rates were equal to, and in some cases were higher (King, Haskell, Taylor, Kraemer, & Debusk, 1991), for home-based interventions among older adults, as compared to center-based interventions (Ashworth, Chad, Harrison, Reeder, & Marshall, 2005). Among adults with chronic disease, adherence and dropout rates have also been shown to be comparable across clinic and home-based interventions (Bullard et al., 2019). In meta-analyses comparing different modes of delivery for physical activity interventions, adherence to home-based physical activity interventions involving contact with staff had similar (Burke, Carron, Eys, Ntoumanis, & Estabrooks, 2006) or higher (Atienza, 2001) adherence compared to standard exercise interventions. Additionally, response rates have been found to be higher for home-based interventions, followed by healthcare interventions and lastly, workplace interventions (Waters, Galichet, Owen, & Eakin, 2011). Home-based interventions may be facilitated using technology. The next following section provides evidence of home-based, technology-delivered physical activity interventions.

Home-based interventions using technology

Utilization of digital health technology may be advantageous for facilitating home practice of yoga. According to data from the Pew Research Center (2019), 81% of Americans own a smartphone. Specifically, among middle-aged adults, 92% of those aged between 30-49 years, and 79% of those between 50-64 years of age own a smartphone. Among those with access to internet, 86% use the internet at least occasionally via a smartphone, tablet, or other mobile device. As of 2018, 42% of US adults use a health-related technology for the purposes offitness and health improvement (Mikulic, 2019a), with young and middle-aged adults represent the highest share of usage (Mikulic, 2019b). In a national sample of adults, 36% reported havinghealth applications on their smartphone, and 60% reported that the applications were useful in helping them achieve their health goals (Bhuyan et al., 2016). In a review of studies on health behavior change using mobile applications, 74% of the studies reported a successful outcome (Zhao, Freeman, & Li, 2016). Studies have used asynchronous and synchronous technology as adelivery mode for home-based yoga interventions. Intervention delivery using synchronous technology refers to the instructor interacting with and providing feedback to participants in realtime, using media such as audioconferencing, videoconferencing or text messaging, through applications such as Zoom or Skype. Asynchronous technology refers to participants being provided with technology to engage in the intervention, without interacting with the instructor inreal-time. Technology interventions may or may not be conducted at home. The following sections will expand upon the use of asynchronous technology, followed by synchronous technology, in studies of yoga, mindfulness, and physical activity conducted at home. In cases where technological and home-based interventions do not overlap, they have been reviewed separately.

Home-based yoga interventions with asynchronous technology

Asynchronous technology such as DVDs and websites has been used to deliver yoga interventions in seven studies. In a 12-week study with participants having myeloproliferative neoplasms (n = 55), although only 37% adhered to the prescription of >60 minutes/week of practice, yoga practice averaged 50 minutes/week among participants (Huberty et al., 2017). Inanother eight-week combined yoga and mindfulness RCT, participants were asked to engage in the program 30-45 minutes/day, six-seven times/week (Kvillemo, Brandberg, & Bränström, 2016). Only 39% in the intervention group completed the study, most of them citing a lack of time. Participants engaged in the program for an average of 3.6 days/week, suggesting that a frequency higher than that, at the prescribed duration, may not be optimal for adherence.

Adherence rates have been higher in other studies. Among cancer survivors, a four-week yoga program delivered through a DVD had an adherence rate was 94.4% (Komatsu, Yagasaki, Yamauchi, Yamauchi, & Takebayashi, 2016), and a nine-week multimodal mindfulness program including yoga had an average completion rate of 70% (Everts, van der Lee, & de Jager Meezenbroek, 2015). In an RCT for cancer survivors who were provided a yoga DVD along with psychological and behavioral support, 75% of the participants used the DVD to engage in yoga an average of three times/week during the eight weeks (Winters-Stone et al., 2018). In a four-week RCT for young and middle aged health care workers, 69% of the participants completed an at-home sun salutation intervention for pain relief, using a DVD, for six minutes/daily (Sakuma et al., 2012). In an RCT for hypertensive adults (n = 115) delivered through a CD for 12 weeks, 78% participated in yoga for at least nine of the 12 weeks (Wolff et al., 2016). While the above studies were completely home-based, asynchronous technology has also been used to facilitate home practice after attending in-person yoga classes. Data on adherence to home practice is described below to offer more insight on the feasibility of conducting a home-based yoga intervention.

Yoga interventions with home practice

In a systematic review of 465 yoga studies, 26% of the studies recommended home practice as a part of their intervention (Elwy et al., 2014). Home practice may be an important component of yoga and physical activity interventions because it provides opportunities for participants to engage in the activity according to their convenience, get a higher dose of the activity, or to get more skilled at the practice (K. J. Sherman, 2012). Additionally, home practice has been associated with mindfulness, subjective well-being, BMI, sleep disturbance, and food consumption, over and above years of practice or class attendance, among a national sample of Iyengar yoga practitioners (Ross et al., 2013). In case of home practice, it has been recommended that materials or facilitation aids be provided (K. J. Sherman, 2012), and these include written instructions using diagrams, yoga mats and blocks, and audio or video CDs and DVDs (Ward, Stebbings, Cherkin, & Baxter, 2014).

Yoga interventions with home practice have shown good adherence rates (Yang, 2007). In 6-month yoga interventions, home practice was performed on 63% of all days (Flegal, Kishiyama, Zajdel, Haas, & Oken, 2007) or 64% of the all days for an average of 38 minutes (Oken et al., 2006). In an intervention of a shorter duration (12-weeks), adherence with home practice was higher, at 86% (Tilbrook et al., 2014). Recently, Greenberg et al (2018) examined whether compliance would differ with varying doses of home practice. In their study assessing the impact of Kripalu yoga on stress reduction, 84 participants were randomly assigned to low, medium, or high dose of yoga via home practice, for a duration of 12 weeks. Participants in the low dose group were asked to practice for 10 minutes/day, six days/week, and those in the high dose group were asked to practice for 40 minutes/day, six days/week. The medium dose group was given flexibility in the duration. Out of six days, they were told to practice for 10 minutes on three days/week, and for 40 minutes on the remaining three days/week. Average adherence was 68%. Adherence was defined as the number of days participants engaged in the prescribed dose of at-home yoga (self-reported) and it was not statistically different (an average of 4 days/week) across the three conditions. In terms of adherence to the minutes, the low dose group showed the highest compliance at 91%, which was significantly different than the adherence of the high (63%) and the medium (58%) dose groups. This study provides promise for engaging in yoga at home, with the best compliance rates for practicing 10 minutes/day.

In completely home-based or partially home-based interventions, compliance was commonly measured through self-report, such as online or paper logs (Carmody & Baer, 2008; Greenberg et al., 2018; Oken et al., 2006; Wolff et al., 2016). In a study to assess validity of self-report measures of home practice, Uebelacker et al (2010) asked yoga practitioners to report on their four-week home yoga practice through daily and weekly online logs. Participants reported on frequency and duration of yoga classes, formal yoga practice (duration > 5 minutes), and informal yoga practice (duration < 5 minutes). Adherence with the 28 daily logs was high, with the majority of the participants (69%) having only four or fewer days missing. Only 19% of the participants had complete entries. The compliance for weekly logs was much higher, with 72% of the participants having complete entries. Participants also reported engaging in yoga at home twice as much as going to yoga classes (*Ms* = 4.38 vs. 2.48). There was good agreement between daily and weekly logs in tracking home yoga practice (ICC between 0.60 and 0.74). This study shows that using weekly logs may provide reliable information about home practice while reducing participant burden.

Physical activity and mindfulness interventions using asynchronous technology

Apart from yoga, physical activity and mindfulness interventions have also used asynchronous technology as a delivery method. Studies have used DVDs to deliver aerobic, strength, or flexibility based physical activities. Among clinical populations, exercise interventions delivered using a DVD along with additional support through emails and phone calls had the following adherence rates to the prescribed exercise protocol: 69% for a six-week intervention (J. Moore et al., 2009), 73.3% for an eight-week intervention (Khalil et al., 2012), 71% for a 16-week intervention (Learmonth, Adamson, Kinnett-Hopkins, Bohri, & Motl, 2017) and 89.2% for a 21-week intervention (Vestergaard, Kronborg, & Puggaard, 2008). In a partially home-based exercise intervention using a DVD to facilitate home exercise, adherence rates were not reported, but dropout was low (<20%) (Hui et al., 2006) and participants reported satisfactionwith the intervention. A six-month RCT among older adults (n = 307) comparing at-home exercise (flexibility, balance, and toning) using a DVD three times/week, to an attentional control group, showed an adherence of 75.7% to the exercise prescription, and improved functional fitness and symptoms of anxiety and depression. On average, >80% of the participantsreported satisfaction with the quality of the content and the program itself (Aguiñaga et al., 2018; McAuley et al., 2013). In an eight-week dance RCT among young adults (n = 45, *M*age = 26 years) who engaged in Zumba for 60 minutes three times/week at home using a DVD, average adherence to the prescription was 87% (Delextrat, Warner, Graham, & Neupert, 2016).

Similar adherence rates have been observed in mindfulness interventions. In an eight-week mindfulness intervention for stress, depression, and anxiety, young adults (n = 26) engaged in mindfulness through videos and reading material hosted on a website. All participants completed the intervention and showed a decrease in stress, anxiety, and reaction time in the Attention Network Task (Spadaro & Hunker, 2016). In a 12-week online mindfulness intervention delivered through 15-minute audio and video modules for with adults with fibromyalgia, the completion rate was 49%, with dropout rate being 15%. Even though the completion rate was low, participants completed an average of 8 out of 12 sessions (M. C. Davis

& Zautra, 2013). In another eight-week RCT among young adults (n = 65), completion rate of a mindfulness intervention for stress reduction delivered via an audio CD was 64% (Warnecke, Quinn, Ogden, Towle, & Nelson, 2011). In a meta-analysis of mindfulness interventions for stress, depression, anxiety, well-being, and mindfulness, 12 of 15 studies delivered the interventions using asynchronous technology such as videos uploaded on a website, or smartphone applications (Spijkerman, Pots, & Bohlmeijer, 2016). The effect sizes for depression and anxiety in these interventions was lower than observed for face-to-face interventions, but that may be attributable to smaller number of studies included in the meta-analysis and variability in study population. Five studies measured adherence, defined as completion of all sessions, and it ranged from 39% to 92%. Jayewardene et al (2017) conducted a meta-analysis of eight online mindfulness RCTs for stress reduction among non-clinical populations. A significantmoderate effect was found for stress reduction over a course of two-twelve weeks, with the highest effect among middle-aged adults. Five of these interventions included regular email or phone calls or tailored feedback to motivate participants. Allexandre et al (2016) randomized participants to asynchronous, synchronous, and face-to-face delivery of a mindfulness intervention for stress reduction. All participants (n = 161, *M*age = 40 yrs.) received access to a website hosting mindfulness classes. The synchronous group additionally met virtually once/week to practice mindfulness and the face-to-face group met three times during the eight- week program. The asynchronous group received an audio CD of the program along with the website access. There were no significant differences between adherence to the program at the end of eight weeks (*M* = 63%), but those in the synchronous and face-to-face groups had a highercompletion rate at one-year follow-up (41% and 48% vs 19%). Overall, there is evidence that physical activity and mind-body interventions delivered through asynchronous technology have good adherence rates, comparable to face-to-face interventions.

Home-based yoga interventions using synchronous technology

Four yoga studies have been conducted using synchronous technology. In a qualitative study by Muntean et al (Muntean et al., 2015), pairs of participants (n = 16) engaged in an unsupervised yoga session at home through video chat applications such as Skype or FaceTime. Limitations included having a limited field of view through the webcam and a lack of physical touch for correcting postures. Yet, participants enjoyed engaging in the session with another person real-time, as it gave a sense of community and accountability. They also did not report having any inhibitions about being watched through the webcam while performing yoga poses, most likely because they already had a social relationship with their partner. In another qualitative study, Addington et al (2018) recruited four women undergoing breast cancer treatment to engage in a yoga intervention through a videoconferencing application (GoToMeeting). Participants practiced yoga for 75 minutes, two times/week, for 12 weeks. While they enjoyed the yoga intervention, they reported having difficulties using the technology. Schulz-Heik (2017) conducted a survey of veterans (n = 64) who engaged in an in-person yoga program or teleyoga offered by Veteran Affairs Medical Center, to examine whether outcomes differed by mode of delivery. There were no significant differences in the number of veterans who attended either class (~30), reported satisfaction level with the classes (M = 82%), or in the outcomes of the program such as self-reported anxiety, depression, and energy level. Donesky et al (2017) conducted a non-randomized study of an eight-week teleyoga among 15 older adults with heart failure and chronic obstructive pulmonary disease (COPD). It was theorized that teleyoga would help people living with COPD overcome many of the serious health issues, such as breathlessness and skeletal muscle myopathy, that restrict travel and accessibility. The yoga teacher engaged with participants twice weekly, through videoconferencing, wherein participantsaccessed live classes on their internet-connected television. Participants could see the teacher andvice versa, but could not see the other participants. Weekly phone calls were made and information leaflets were mailed out each week for additional support. Intervention feasibility was assessed via safety, adherence, and acceptability. Adherence to the intervention was high, with a mean attendance rate of 14.5 out of 16 classes (90%). The intervention was deemed as safe as no emergency room visits occurred due to the intervention, and the mean heart rate, oxygen saturation rate, and perceived exertion stayed within safe levels. Acceptability was high, with high mean scores for enjoyment, and low scores for perceived difficulty. However, participants reported having difficulty using the videoconferencing technology in 45% of the classes and only 23% of the classes were without technical issues.

Physical activity and mindfulness interventions with synchronous technology

Physical activity studies have been conducted using synchronous technology and have also been compared to other delivery methods. Taylor et al (2009) conducted a study with older adult stroke patients (n = 12), involving one hour of aerobic and strength exercise, twice/day, for 9 weeks. Participants and caregivers interacted with the staff through a television connected via optical transport network. The remote participants attended an average of 70.4% of the sessions and no adverse events were observed. Other studies conducted with older adults involving aerobic, strength, or balance exercise sessions through videoconferencing, for the purpose of rehabilitation, have shown average adherence rates of 87% (Lai, Woo, Hui, & Chan, 2004), and 97% (Russell, Buttrum, Wootton, & Jull, 2004). Taetzsch and colleagues (2019) compared a face-to-face and videoconference delivered multi-component weight loss program which included 150 minutes of exercise/week for 12 weeks, among adults (*M*age = 42 years). The average attendance rate for both groups was high (90%). Retention rate, referring to participants who did not dropout of the study, was significantly higher for the remote delivery method than face-to-face contact (*Ms* 96% vs 70%). In a 10-week RCT for cancer survivors engaging in 90 minutes/week of moderate intensity aerobic exercise, retention rate was 89% and adherence to the prescribed exercise dose was 84% (Courneya et al., 2003). In a 12-week RCT for cardiac rehabilitation among adults (*M*age = 61 years), an aerobic exercise program was delivered at home, three times/week, through telemonitoring and tele-feedback, compared to face-to-face contact (Rawstorn et al., 2018). Participants were provided with a sensor that tracked their physiological responses such as heart rate and respiratory rate, which was connected to a smartphone application that provided staff real-time access to participants' data, allowing for remote coaching and monitoring. While adherence to the prescribed exercise was lower than other studies in the intervention group (M = 58%), it did not differ significantly from the control group (M = 63%). In another internet-based intervention to promote physical activity, there wereno significant differences in intervention effectiveness when comparing internet delivery to face-to-face delivery (Steele, Mummery, & Dwyer, 2007). In a systematic review of home-based physical activity interventions for older adults, Geraedts and colleagues (2013) found home- based interventions that use non-frequent or frequent telephone contact, or direct remote feedback to be as effective as supervised exercise programs. Particularly, direct remote feedback seemed to be a good alternative to onsite exercise programs. In studies that measured adherence, it was >60%, except for one study.

Krageloh and colleagues (2019) conducted a videoconference-delivered mindfulness RCT among University students and staff (n = 32, *M*age = 30 years). Participants met as a group at a location in the University, and were connected with the facilitator through a videoconferencing application (GoToMeeting). Sessions were conducted once/week for 90 minutes and included breathing exercises, meditation, mindful movement, and educational material. Average attendance to the sessions was 71.33%. Participants who attended at least 5 of the 6 sessions were significantly better on outcomes such as depression, anxiety, and negative affect, as compared to the control group. In another 12-week RCT for stress reduction, a mindfulness program delivered in-person (n = 44) was compared to online delivery (n = 52), once/week for 60 minutes. There was significantly lower dropout in the online group (3.8%) as compared to the in-person group (27.3%), and the results were equivalent across both the groups (Wolever et al., 2012). Aikens et al. (2014) conducted a seven-week RCT for stress reduction among employees (n = 44) which included online mindfulness training once/week for 60 minutescompared to a waitlist control. The intervention included seated and standing mindfulness movements, body scan, breathing exercises, and mindfulness exercises, along with strategies to promote behavior change. Among the completers, 82.4% completed more than 75% of the program, attended an average of 79.1% of the sessions, and showed significant improvement in measures of stress and mood. Similarly, an eight-week RCT comparing online-delivered mindfulness for stress reduction which included a 2 hour weekly practice of hatha yoga, Qigong, and meditation, in comparison to a waitlist control group, was conducted among cancer survivors(n = 62, Mage = 58 years) (Zernicke et al., 2014). The average number of sessions attended by participants was 66% and average engagement in home practice was 150 minutes/week. All participants reported being satisfied with the program and showed significant improvement in stress symptoms and mindfulness, as compared to the control group. In another eight-week intervention among participants with depression, weekly mindfulness classes were delivered online either through the phone or the internet. 73% of the participants completed more than 50%of the intervention with no particular difference between the delivery modes, and results showed a reduction in symptoms of depression (Thompson et al., 2010). Overall, conducting a home- based yoga intervention may be feasible and beneficial, per evidence from the studies above. Thenext sections will highlight theoretical constructs guiding technology-delivered behavior change interventions.

Technology acceptance model

The Technology Acceptance Model (TAM) has been used as a conceptual framework to understand the processes behind participants' use and acceptance of technology. TAM was developed based on a behavioral theory to inform the design and implementation of new information systems, and to provide a theoretical basis to test a consumer's acceptance of the technology (F. Davis, 1985, 1989). TAM primarily focuses on two determinants of technology usage—perceived utility and ease-of-use—as well as attitudes towards the technology. According to theory and empirical validation studies, perceived ease-of-use has a direct effect on perceived usefulness. These psychological constructs, in turn, influence the user's intention to use the technology (behavioral intent), which influences user behavior. The relationship between perceived usefulness and behavioral intent is stronger than between perceived ease of use and behavioral intent (Y. Lee et al., 2003). Apart from these, there are other variables that affect behavioral intention to use the technology, such as computer anxiety, self-efficacy, enjoyment, and experience (Y. Lee et al., 2003). There are also personal and external factors that affect perceived usefulness and ease of use (Figure 1).

TAM has been supported in studies investigating the use of technology for physical activity purposes. Lunney, Cunnigham, and Eastin (2016) assessed the adoption of wearable fitness trackers for the purpose of engaging in physical activity, among working adults in the US.They found that perceived usefulness and attitude towards the device influenced participants' acceptance of the device and both perceived usefulness and perceived ease of use were direct predictors of the fitness tracker usage. Similarly, perceived usefulness and attitudes were predictive of the behavioral intention to use a gamified health management app (Wen, 2017). In another study, willingness to continue using a fitness application was predicted by perceived usefulness, perceived ease of use, and social norms (Beldad & Hegner, 2018). While TAM may be effective in explaining the use and acceptance of physical activity technology, it has been suggested that TAM be integrated with theories that include additional variables related to behavioral change (Legris, Ingham, & Collerette, 2003).

Social cognitive theory

Interventions using constructs rooted in theory are significantly more successful than those that are not theory based (Glanz & Bishop, 2010). Social Cognitive Theory (SCT) is a theoretical framework that has been applied to guide behavioral change interventions. SCT proposes that there is reciprocal causal interaction between three sets of factors, namely, cognitive, behavioral, and environmental, that motivate and sustain an individual's behavior (Bandura, 1977). Self-efficacy, self-regulation, and outcome expectations are important constructs in this theory that predict maintenance of health behaviors, including physical activity.

Self-efficacy is confidence in one's ability to do a particular task successfully. Self-efficacy has been repeatedly found to be one of the most important factors influencing participation in, and continuation of, physical activity behavior. In a review of interventions using the SCT versus other theories of behavior change, SCT constructs predicted participation in four weeks of physical activity, with self-efficacy accounting for most of the unique variance

(Dzewaltowski, Noble, & Shaw, 1990). Self-efficacy has been shown to be an important and consistent predictor of physical activity maintenance, in a review of 44 studies using SCT constructs (Young, Plotnikoff, Collins, Callister, & Morgan, 2014) and in other reviews (Rhodes & Nigg, 2011). Self-efficacy is theorized to be increased from four sources of information: mastery experiences, vicarious experiences, social persuasion, and individuals' perceptions of physiological and affective responses to behavior (Bandura, 1977). Mastery experience is theorized to be the most effective source of self-efficacy, but all sources of self-efficacy may be important depending on the time and context of the intervention (Gao, Xiang, Lee, & Harrison, 2008). Mastery may be important in the beginning of the intervention (Gao et al., 2008), especially to ensure proficiency in the motor movements, before progressing to more difficult movements. Feedback on performance and vicarious experience are also associated with high levels of self-efficacy (Ashford, Edmunds, & French, 2010). By having a supervised intervention along with feedback, before progressing toward the unsupervised part, mastery experience can be facilitated for the participants. Another review of 22 studies among healthy adults found that self-regulatory strategies were also a predictor of physical activity (Rhodes & Pfaeffli, 2010). Self-regulatory strategies include planning, goal-setting, and self-monitoring of behavior.

Self-efficacy and self-regulatory strategies are a part of behavior change techniques (BCTs). It is important to use theory and evidence-based behavior change techniques to sustain physical activity during and after the intervention. Michie and colleagues (2009) conducted a meta-analysis to identify the most effective BCTs to promote physical activity and healthy eating, from a list of 26 BCTs. Self-monitoring (monitoring one's change in behavior through logs or diaries), combined with at least one technique from control theory, such as goal-setting or feedback on performance, was significantly more effective than other techniques. In a systematic review conducted specifically among internet-based physical activity interventions, self-monitoring and feedback were the most commonly used BCTs (Van Den Berg, Schoones, & Vlieland, 2007). However, in a meta-analysis of internet-based physical activity interventions, providing educational content, and not self-monitoring and goal setting, significantly moderated increases in physical activity (Davies, Spence, Vandelanotte, Caperchione, & Mummery, 2012). It is to be noted only 26% of the studies in this meta-analysis included participants who were physically inactive at baseline, which was a significant moderator of intervention effectiveness. The effectiveness of BCTs may differ based on whether participants are inactive or active at the beginning of the intervention.

Studies have specifically examined which BCTs may be most effective in technology-based health interventions, including physical activity. In a content analysis of lifestyle activity monitors such as Fitbit (Lyons, Lewis, Mayrsohn, & Rowland, 2014), and smartphone applications for health behaviors (Zhao et al., 2016), the most commonly present BCTs were self-monitoring and provision of feedback. In a review of studies (n = 14) using BCTs in e-health physical activity interventions for people with cardiovascular disease, the most commonly used BCTs were information about consequences, goal-setting, and self-monitoring (Duff et al., 2017). Similarly, e-physical activity interventions for people with diabetes included BCTs such as feedback, barrier identification, and self-monitoring (Van Vugt, De Wit, Cleijne, & Snoek, 2013), and instruction, adding technology, information about consequences, and self-monitoring (Kebede, Liedtke, Möllers, & Pischke, 2017). Webb and colleagues (2010) conducted a meta-analysis of internet interventions (n = 85) for a variety of health behaviors. Results showed that interventions based on behavior change theory had a significantly higher effect than those that were not theory-based. The most common BCTs used in these interventions were providing information on consequences of the behavior, self-monitoring, and identifying barriers. Modeling, relapse prevention/coping planning, facilitating social comparison, goal setting, action planning, and provision of feedback on performance had a small significant effect on change in behavior. Genugten and colleagues (2016) further conducted a meta-analysis of the above studies to examine the interaction between BCTs and different modes of technological delivery. No synergistic effects were found between delivery modes and BCTs, but they found that interventions using barrier identification and providing rewards for change were the least effective, as compared to interventions that used other combinations of BCTs. Overall, self-regulatory strategies, such as self-monitoring, and strategies to improve self-efficacy, such as providing instruction and feedback, seem to be the most popular and effective BCTs in internet-based physical activity interventions.

While SCT and BCTs has been widely applied to increase exercise adoption and maintenance, there are few studies that have applied these constructs to yoga interventions. Among breast cancer survivors, a SCT-based yoga intervention for improving arthralgia was designed to promote self-efficacy whilst engaging in the yoga intervention through performance accomplishment, structured experience, verbal support, and physical feedback (Galantino et al., 2012). Middle-aged women (n = 10) attended two Hatha yoga classes per week, for six weeks. However, self-efficacy was not assessed at the end of the intervention. Participants reported experiencing a feeling of community and empowerment, among other benefits. Mehta and Sharma (2011) conducted a 10-week yoga intervention for alleviating anxiety, involving knowledge, self-efficacy, outcome expectations, and outcome expectancies for yoga. Along with postures, breathing, and meditation, each 50-minute yoga session included discussions about the benefits of yoga (outcome expectations), gradual progression of yoga postures and exposure to role models (self-efficacy), role plays of breathing exercises, positive reinforcement, and weekly reminders of these strategies. The control group was given the same yoga intervention without addressing the constructs of SCT. Knowledge, self-efficacy and outcome expectations increased in both the groups, whereas anxiety decreased only in the control group, possibly due to a higher increase in self-efficacy. Sharma (2001) conducted a Kundalini yoga intervention among middle-aged participants (n = 31) and examined its effect on SCT-based constructs. Knowledge, outcome expectations, and self-efficacy for yoga and yoga postures increased significantly after the intervention. The same SCT-based yoga intervention was implemented for smoking cessation among young to middle-aged adults (n = 21) in a RCT (M. Sharma & Corbin, 2006), and included multi-site yoga classes, a yoga video to facilitate home practice, and phone calls from staff members to encourage smoking cessation. Self-control for quitting increased in the yoga group and decreased in the self-help control group at the end of the intervention, whereas no change was seen in self-efficacy for yoga or quitting, in contrast to the non-randomized study. It is to be noted that the attrition rate in this study was quite high (66.7%). In a RCT among females with PTSD (n = 38), a Kripalu yoga intervention (vs. control) was held once/week for 75 minutes, for 12 weeks. While the intervention did not explicitly address components of SCT, self-efficacy and self-regulatory strategies were assessed at baseline and end of the intervention (Martin, Dick, Scioli-Salter, & Mitchell, 2015). The yoga group did not change significantly on these variables but showed a significant decline in external self-regulation, implying a shift toward internal motivation. An RCT among older women with knee osteoarthritis showed a positive association between self-efficacy and adherence. SCT was used to increase adherence to a 8-week yoga program along with home practice (Cheung, Wyman, & Savik, 2016). The intervention included demonstration of yoga poses and individualized feedback by the instructor to promote observational learning, strategies to promote self-efficacy and positive outcome expectations, and a 5-minute discussion before every session regarding the participants' specific concerns. Baseline self-efficacy for exercise was significantly correlated with adherence to the yoga class. Overall, preliminary evidence from these studies shows that strategies to target SCT constructs in yoga studies may increase self-efficacy and self-regulation, in turn affecting outcomes, and increasing adherence. Given that yoga is different from physical activities such as walking, more rigorous research (e.g. RCTs) is needed to understand how self-efficacy may be optimized in a yoga intervention for improving adherence and study outcomes. See Figure 2 for self-efficacy and self-regulation strategies used in this study.

Yoga as physical activity and overall health

As mentioned previously, Hatha yoga is the most popular form of Yoga in the US. Hatha means to 'hold firmly or closely.' Hatha yoga is said to be the path through which one builds willpower and perseverance (Svatmarama & Iyengar, 1992) and includes maintaining postures in isometric contraction while standing, sitting, or lying down on the back or stomach, coupled with breathing and meditation exercises. Hatha yoga is an umbrella term that includes different styles of yoga that vary in their speed, difficulty of postures, or the type of movement, among other aspects (Morone & Greco, 2007), and is most suitable for beginners. One popular style derived from Hatha yoga is Iyengar Yoga, which involves the use of straps and blocks to aid body alignment, intended to suit populations with physical ailments or chronic disease and beginners. Since aids are provided, practitioners who have issues such as physical ailments, poor body structure, poor proprioception, or less flexibility can slowly perfect their postures, with minimum risk of injury. Other styles derived from Hatha yoga are more vigorous, such as Ashtanga Yoga and Bikram Yoga. Some forms, such as Vinyasa yoga, focus on the flow of movement and can be of low or vigorous intensity, as the flow of movement is moderated by the instructor. Most styles incorporate postures, breathing and meditation in some way or the other (Mehta & Sharma, 2011). Hatha yoga is the most common form of yoga used in yoga interventions in research, and is the most commonly practiced in the US. Yoga interventions have been conducted with a wide variety of populations, and for a variety of health outcomes, as reviewed below.

Clinical populations

Yoga has been tested as a form of symptom management or a complementary form of treatment among clinical samples. These studies have examined whether yoga, when compared to other physical activity modalities, or no physical activity, improved cognition, mood, fatigue and other aspects related to well-being. Among participants with multiple sclerosis (MS), evidence suggests yoga is equally effective as aerobic exercise for improving energy and vitality (Oken et al., 2004), response inhibition (Sandroff, Hillman, Benedict, & Motl, 2015) and better than aerobic exercise in improving attention (Velikonja, Čurić, Ožura, & Jazbec, 2010), but had no effect on some other cognitive tasks (Oken et al., 2004). A meta-analysis showed that yoga was useful for improving mood and fatigue in participants with MS but not for muscle function, cognition or health-related quality of life (Cramer, Lauche, Azizi, Dobos, & Langhorst, 2014).

Yoga has been effective among participants with type-2 diabetes in improving aspects of cognitive function (Kyizom, Singh, Singh, Tandon, & Kumar, 2010; Mohanty, Metri, Nagaratna, & Nagendra, 2015; Satish & Lakshmi, 2016). Several systematic reviews show positive effects of Yoga on other symptoms and outcomes of diabetes such as glucose levels (Aljasir, Bryson, & Al-Shehri, 2010; Innes & Vincent, 2007; Upadhyay, Balkrishna, & Upadhyay, 2008), although long term effects are still inconclusive and more high quality studies are required. Systematic reviews have shown that yoga can modify biological risk factors for cardiovascular disease (CVD), such as blood pressure and total cholesterol (Cramer, Lauche, Haller, et al., 2014; Hartley et al., 2014; Raub, 2002) as well as CVD risk factors associated with insulin resistance syndrome (Innes, Bourguignon, & Taylor, 2005) and risk factors for metabolic syndrome (P. Chu, Gotink, Yeh, Goldie, & Hunink, 2016). Overall, most reviews concluded that more high-quality studies are required to draw clear conclusions as there may be a high risk of bias in the studies reviewed, but there was preliminary positive evidence for the benefits of yoga to these clinical populations. Similarly, systematic reviews have shown positive results for yoga intervention in populations with cancer (Buffart et al., 2012), chronic low back pain (Cramer, Lauche, Haller, & Dobos, 2013), and chronic neck pain (Cramer, Klose, Brinkhaus, Michalsen, & Dobos, 2017).

Mental health disorders

Yoga interventions have been conducted for symptom management in patients with neurological, psychiatric or mental health disorders, although the evidence is at its preliminary stage. A review of yoga interventions for participants with epilepsy, stroke, Alzheimer's disease, fibromyalgia, and peripheral nervous system disorders investigated the efficacy of yoga as an adjunct to their usual treatment. Results showed that yoga was beneficial for symptom management, such as improvement in mobility and reduction in stress, seizures, depression and fatigue (Mishra, Singh, Bunch, & Zhang, 2012), similar to a review on schizophrenia, depression, anxiety, and post-traumatic stress (Cabral, Meyer, & Ames, 2011). In both reviews, the evidence was limited by lack of RCTs, small sample sizes, participant non-blinding, and short duration of studies. Similar positive results have been shown in reviews for other mental health disorders. For example, Balasubramaniam, Telles, & Doraiswamy's (2013) systematic review of RCTs targeting major psychiatric disorders concluded that yoga may be effective as an adjunct form of therapy for mild depression, schizophrenia, ADHD in children, and sleep disorders, but more high-quality research is necessary to draw a conclusion. These findings are supported by another systematic review of RCTs for neurological and psychiatric disorders, wherein more than 50% of the studies reviewed found positive evidence for symptom management of the disorders (Meyer et al., 2012). Other systematic reviews have found a moderate effect size for yoga among people living with schizophrenia (Cramer, Lauche, Klose, Langhorst, & Dobos, 2013) and anxiety (Kirkwood, Rampes, Tuffrey, Richardson, & Pilkington, 2005). However, researchers have refrained from making any recommendation due to high risk of bias in the studies (Cramer, Lauche, Klose, et al., 2013) and due to poor methodological quality of studies (Kirkwood et al., 2005).

Some studies have assessed cognitive functioning among participants with mental health disorders. Among patients with major depression, engaging in Sahaj yoga (along with anti-depressant medicine) for 8 weeks resulted in improvements in tests of processing speed and working memory (V. Sharma, Das, Mondal, Goswami, & Gandhi, 2006). Studies have shown change in the biomarkers of neuroplasticity, such as brain derived neurotrophic factor after engaging in yoga, in patients with depression (Naveen et al., 2013, 2016; Tolahunase, Sagar, Faiq, & Dada, 2018).

Yoga for stress and anxiety reduction

Apart from clinical populations, yoga has been widely used for management of stress and general anxiety (non-clinical), among different populations such as school and college students, employees, and military personnel. In a randomized cross-over study designed to test yoga in its natural environment, part and full-time workers (n = 90) experiencing moderate to high stress, were randomized to either an 8-week or 16-week yoga intervention. Both groups participated in power yoga twice a week for 60 minutes, and displayed a decrease in stress and anxiety, coupled with an increase in general well-being (Maddux, Daukantaité, & Tellhed, 2018).

These findings are corroborated by several studies on yoga as an intervention for stress or anxiety reduction (Brems, 2015; Cowen & Adams, 2005; Hartfiel, Havenhand, Khalsa, Clarke, & Krayer, 2011; Huang, Chien, & Chung, 2013; Rocha et al., 2012; Sakuma et al., 2012; Tsang, Chong, Tsunaka, Chan, & Cheung, 2011; Wolever et al., 2012). For example, in study specifically addressing stress among full-time working adults through worksite and home-based yoga intervention, engaging in yoga for one hour/week either in-person or online was associated with reduction in perceived stress after 12 weeks (Wolever et al., 2012). Another study conducted a 10-week yoga program for stress reduction among University employees (Brems, 2015). The yoga sessions were held once a week for 90 minutes and participants were provided with detailed outlines of each class to facilitate practice at home. Participants adhered well to the intervention (88%) and it resulted in a reduction of psychosocial and physical stress. All of these studies include self-reported measures of stress, and studies with physiological measures of stress are reviewed in another section.

Self-reported stress. In a systematic review by Sharma (M. Sharma, 2011) about the impact of yoga on stress symptoms, it was seen that 12 out of 17 studies had a positive outcome. Among these, the duration of longitudinal studies was usually around 60 minutes, 3 times a week. One study had a duration of 35 minutes of yoga practice, performed daily, for 6 weeks, and two other studies had 60 minutes once per week, and yet showed positive effects. The yoga employed in these was Dru yoga, which is form of yoga emphasizing flowing and connected movements. One study with a dose of 60 minute once per week did not show any significant effect on perceived stress after 8 weeks, whereas one Hatha yoga study which showed positive effects had 90-minute sessions once a week. This review did not examine the dose-response relationship of the duration and frequency of yoga with the outcomes, but it seems that dose may play an important role.

Similarly, another systematic review (Chong, Tsunaka, Tsang, Chan, & Cheung, 2011) about yoga and stress that reviewed only RCTs (four) and clinical control trials (four), reported primarily positive outcomes. The frequency ranged from one to 10 sessions per week, and duration ranged from 60 to 180 minutes/session. Yoga was as effective as dance exercise, cognitive behavioral therapy, and relaxation. Most of the studies on anxiety and/or stress reduction are focused on hatha yoga and Iyengar yoga, with some studies on Sudarshan Kriya yoga, integrated yoga, Viniyoga, Bikram yoga, Dru yoga or Kripalu yoga. Altogether, this body of work has highlighted the need for more high-quality yoga studies examining the impact on stress among healthy populations. Chu and colleagues (2014) conducted a systematic review of RCTs and quasi-experimental studies investigating the effect of yoga (five studies) or traditional physical activity on stress and anxiety among healthy full-time working adults. The frequency of sessions ranged from one to three times per week, and the duration ranged from eight minutes to 60 minutes per day for two to 12 weeks. All yoga studies showed a decrease in stress or anxiety post-intervention.

Although a majority of yoga studies involve sessions lasting ~60 minutes, Sakuma and colleagues (Sakuma et al., 2012) tested a brief yoga intervention involving eight minute-sessions per day over the course of four weeks. They used DVDs to deliver the intervention that involved sun salutation and breathing exercises. On average, participants engaged in yoga four times per week for the first two weeks, and three times for the last two weeks. At the end of four weeks, participants in the yoga group had significantly reduced anxiety levels.

Berger and Owen (1988) proposed a taxonomy of exercise for stress reduction, and hypothesized that activities that are aerobic, noncompetitive, predictable, rhythmic, of moderate intensity, and performed for at least 20-30 minutes regularly, would have the most effect on stress reduction. Yoga meets most of the parameters of this taxonomy except for being an aerobic activity that is moderate in intensity. However, some aspects or types of yoga, such as sun salutation, Ashtanga yoga, or power yoga meet all the parameters. To test the validity of their classifications, researchers examined the effect of swimming, body conditioning, hatha yoga, fencing, and exercise on stress reduction, in comparison to an attentional control group. They found that the yoga group reported better mood profile and less depression and anxiety, while those in the swimming group reported less tension and confusion, but no changes in depression and anxiety, contrary to their hypothesis. However, in accordance with their hypothesis, both groups were better as compared to the fencing group and the attentional control group. Another study for identifying essential components of yoga interventions for reducing depression and anxiety reached a consensus that ‘coordinated flow of breath with movement’ was considered important or essential for reducing both anxiety and depression, and recommended that yoga postures be repetitive, include dynamic movements involving chest-openers and back bends (rather than holding poses for long), while focusing on breathing, such as sun salutation (de Manincor et al., 2015). Overall, there is evidence that yoga is a promising approach to manage non-clinical stress and anxiety.

Yoga and cognition

In the past decade, research on effects of yoga on cognitive functioning among healthy adults has increased. In two reviews covering more than 15 studies across the lifespan, both acute and chronic yoga studies showed a positive association of yoga with aspects of executive functioning (Gothe & McAuley, 2015; Luu & Hall, 2016). Most of these studies focused on Hatha or Iyengar yoga, across the lifespan. More studies measured attention, processing speed, and executive function as compared to memory. Both the reviews highlighted the need for more RCTs, with larger sample sizes, in order to draw clear conclusions because there was insufficient evidence for a cognitive effect of yoga. The studies reviewed below are restricted to healthy adults.

Gothe and McAuley (2015) found a stronger effect (g=.56) on cognition among acute studies, as compared to chronic studies (g=.33), with the strongest effect for memory, followed by attention and processing speed measures, and executive functions. While attention and memory can be considered a part of executive functioning (Diamond, 2013), the authors differentiated them and calculated effect sizes separately. In contrast, the effects of chronic RCT yoga interventions were strongest for tasks of attention and processing speed, followed by executive functioning, and lastly, memory. The majority of acute studies were conducted among healthy young adults whereas a number of the longer-term studies investigating chronic effects targeted older adults or patients living with chronic diseases. The effect on cognition may be age-specific, with cognitive domains being differentially affected. Nevertheless, positive effects on cognition were seen in young, middle-aged, and older adults. The duration of sessions in the RCTs ranged from 45 minutes to 90 minutes, and frequency ranged from one to five times per week.

Since 2015, more studies have been conducted exploring this relationship. For example, Luu and Hall (2017) compared an acute session of Hatha yoga with mindfulness meditation and a reading control condition. Young and middle-aged adults engaged in 25-minute counterbalanced sessions of yoga, mindfulness, or reading, and were assessed 5 minutes and 10 minutes after the session. Both hatha yoga and mindfulness meditation resulted in better inhibition control assessed by the Stroop task, and better mood at the 10-minute mark as compared to the control group, although hatha yoga had a slightly larger effect on Stroop. There was a significant difference in the vigor-activity score of the *Profile of Mood States*, favoring the yoga group over the mindfulness group. Overall, combining physical activity with mindfulness did not enhance the cognitive impact as compared to mindfulness alone. In another acute study young adults engaged in yoga, aerobic exercise, and rest, for 20 minutes on separate occasions (S. M. Moore, Peterson, & Welsh, 2019). The yoga condition was significantly better as compared to aerobic exercise on the accuracy scores for the flanker task, but it was not different from the aerobic condition on the trail making task. This study was also one of the first to examine executive function domains of planning and problem solving, assessed via the tower of London task, and found no difference among the three conditions.

Apart from the acute studies mentioned above, chronic studies have also been conducted. Gothe et al conducted an RCT comparing yoga to a stretching-strengthening control group conducted 3x/week for 8 weeks, among older adults. Yoga participants performed better on the attentional network task, components of the trail making task, and pattern comparison test as compared to the control group (Gothe, Kramer, & McAuley, 2017). While this study used an anaerobic control group, some studies have used aerobic activity control groups. In a study comparing participants engaging in yoga vs aerobic exercise for 90 minutes, 6 days/week, both groups improved on tasks measuring executive functions after, among young and middle-aged substance abuse users (Gaihre & Rajesh, 2018). In contrast, another study showed that engagingin yoga for 12 weeks improved auditory and visual reaction time and oxygen consumption, as compared to the aerobic activity group engaging in swimming (Sawane & Gupta, 2015). No yoga and cognition chronic studies have been conducted specifically among a sample of full- time working adults.

Apart from assessing cognitive functioning through neuropsychological tests, research has investigated the cognitive effects of yoga using brain imaging techniques. These techniques provide a more in-depth understanding of the brain structures and functions affected by engaging in yoga, provide a neural basis to the cognitive benefits noted, and thus aid in understanding the potential mechanisms by which yoga may affect cognitive processes. While this research has been done among clinical populations as well, the studies described here are restricted to relatively healthy adults, as the pathology may be different for these populations.

A number of studies have examined the neural differences between yoga practitioners and non-practitioners. These studies provide a basis that engaging in yoga for a long period of time is associated with neural changes, and also serve as a platform for determining which structures and functions might be affected. Using a voxel based morphometry analysis, Froeliger, Garland, & McClernon (2012) found that young adult yoga practitioners (n = 7) showed greater grey matter volume, which is associated with neuroplasticity, in the frontal, temporal, occipital, limbic and cerebellar regions as compared to matched controls. They also had fewer self-reported cognitive failures. Similar results were found in other studies wherein yoga practitioners had greater gray matter volume in the hippocampus (Gothe, Hayes, Temali, & Damoiseaux, 2018) or in multiple brain regions which showed a linear growth with more yoga experience, as well as higher cortical thickness (Villemure, eko, Cotton, & Bushnell, 2014). Among young adults doing a 30-day santhi kriya yoga course that required participants to engage in yoga daily for 50 minutes, alpha wave activity increased in the pre-frontal cortex and occipital lobe, over time (Satyanarayana, Rajeswari, Jhansi Rani, Sri Krishna, & Krishna Rao, 1992).

While prior studies focused on functional brain changes between yoga practitioners and controls, Cohen et al (2009) conducted one of the first studies examining whether Iyengar yoga training in adults naïve to yoga altered cerebral blood flow measured after rest and after a 10 minute meditation, before and after the program. The 12-week yoga program was focused on postures, breathing exercises, and meditation. Their study was a case series with a sample size of 4 and no control group. They found increased percentage change in cerebral blood flow in parts of the frontal lobe and right sensorimotor cortex post intervention as compared to baseline. In another study, brain scans were conducted before and after a 6-month yoga program among elderly participants (n = 7) without a control group (Hariprasad et al., 2013). They reported an increase in the hippocampal gray matter volume after 6 months of yoga practice including postures and breathing exercises. In another study, Froeliger, Garland, Modlin, and McClernon (2012) measured neural substrates of emotion and cognitive function, and their interaction, by assessing the activation in amygdala and prefrontal cortex during an affective-cognitive task, in young healthy Hatha yoga practitioners vs. controls. Whereas there was no difference in the reaction time for Stroop task between the two groups, they observed a significant difference in their brain activation patterns. Yoga practitioners showed less brain activation in the dorsolateral prefrontal cortex (dlPFC, associated with cognitive control and goal-directed processes) to all images, and higher activation in the ventrolateral PFC (associated with inhibitory control) while viewing negative images during a cognitively demanding task, as compared to the controls. Both groups showed similar amygdala activation to the negative images, but this was associated with adecrease in positive affect only for the control group. Overall, yoga practitioners showed a favorable affective-cognitive response that involved cognitive attempts to disengage from emotional stimuli in the face of cognitively demanding tasks but not otherwise, and less negative affective response. While this is a step forward in understanding how emotional and cognitive processing may be related, they acknowledge that the exact neural basis of the emotion-cognitioninteraction as a result of yoga practice is not yet known.

Recently, Desai, Tailor, and Bhatt (2015) conducted a review of studies examining the neuropsychological effect of yoga using brain imaging techniques. Different studies reported increases in alpha waves (Nagendra, Kumar, & Mukherjee, 2015; Satyanarayana et al., 1992; V. Sharma et al., 2006; Stančák & Kuna, 1994; Trakroo, Bhavanani, Pal, Udupa, & Krishnamurthy, 2013), beta waves (Bhatia, Kumar, Kumar, Pandey, & Kochupillai, 2003; Nagendra et al., 2015), theta waves (Trakroo et al., 2013; Vialatte, Bakardjian, Prasad, & Cichocki, 2009), delta waves (Nagendra et al., 2015; V. Sharma et al., 2006) and gamma waves (Vialatte et al., 2009), or a decrease in theta and gamma waves (Nagendra et al., 2015). The review was not limited by any particular style of yoga. Overall, studies including breathing practices showed an increase in alpha or beta waves, and the only study including asana showed an increase in alpha and theta waves. Thus, the research is equivocal in terms of which brain waves are most affected by breathing practices, and it may be that different yoga components have a differential effect on brain waves. It is important to consider that most of the research was focused on breathing techniques in yoga practice, and it may not representative of yoga practice when it includes the other aspects as well (postures and meditation). The sample size of these studies was quite small and all studies had young to middle aged participants. Except for one study that had a sample size of 80, all the studies had a sample size less than 30 participants. Overall, it seems that research on the impact of yoga on brain waves is in preliminary stages owing to small sample sizes, non-randomized studies, variation in yoga techniques and focus on some components but not others, though it is in the positive direction.

Theoretical explanation of cognitive effects

Attentional control theory

The Attentional Control Theory (ACT), proposed by Eysenck and colleagues (2007) is a modification of the Processing Efficiency Theory by Eysenck (1993), both of which relate to the relationship between anxiety and cognitive functioning as described by Baddeley's working memory model (Baddeley, 1996). According to the ACT, presence of non-clinical anxiety among healthy populations is associated with an impairment in the functions of the central executive, i.e. inhibition, shifting, and to a weaker extent, updating. These three functions are the one's identified by Miyake et al (2000) as constituting executive functioning, and they are described as follows: Inhibition- an individual's ability to inhibit automatic and dominant responses when necessary, in order to continue focusing on task relevant stimuli; Shifting- moving back and forth between multiple tasks or mental sets depending upon the relevancy of the task; and Updating- the exploitation of working memory such that information is coded, monitored, and manipulated based on relevance to the present task.

According to this theory, anxiety affects a person's ability to inhibit task-irrelevant stimuli, thus directing processing resources away from task-relevant stimuli. These irrelevant stimuli could be external, or internal, such as worry. This in turn, affects processing efficiency, which is the optimum allocation of cognitive resources for a task. They theorize that those high in anxiety need to allocate more resources to complete a task as compared to those low in anxiety, and it is often reflected in higher reaction times for the task. However, anxiety may or may not affect performance effectiveness, which refers to the end result of the task, such as accuracy. According to this theory, attentional control also depends on two systems- top-down goal directed, and bottom up stimulus-driven (Corbetta & Shulman, 2002). The top-down goal-driven system is based on knowledge and one's current goals, and functions via the higher order brain centers such as the frontal cortex, to allocate attention according to one's goals. In contrast,the stimulus-driven bottom up system is driven by responding to the most salient stimuli irrespective of their task relevance, and does not involve the higher order brain centers. Anxiety disrupts the balance between these two systems, by disrupting the functions of the goal-directed system and enhancing the processing of the stimulus-driven system in presence of stimuli, leading to decreased processing of task relevant stimuli. In the review of evidence provided by Eysenck et al (2007), anxiety impaired processing efficiency, and in some cases performance effectiveness on tasks of response inhibition such as the Stroop task, and task switching such as the Wisconsin Card Sorting Task, as well as dual tasks and working memory tasks. Deficits in executive functioning, in turn, affect an individual's ability to carry out daily tasks efficiently, and full-time working adults with high anxiety may not be able to do their work efficiently.

As mentioned previously, presence of stress or anxiety is associated with an increase in cortisol levels. The next section is focused on the neuropsychological system controlling cortisol levels, and how yoga potentially affects cognitive functioning by its influence on this system. While ACT explains the potential relationship of stress/anxiety with cognition, it does not explain how interventions designed to reduce stress may play a role in affecting cognitive functioning. However, based on evidence presented above, and in the following sections about the impact of a yoga on neuropsychological factors, it is likely that physical activity mediates the effect of anxiety or stress on cognitive functioning. A mind-body activity like yoga may have a stronger impact considering that it has an active attentional component during practice. The findings from this study will contribute to and can be explained by this theory (see Figure 3).

Downregulation of the Hypothalamus-Pituitary-Adrenal axis (HPA axis)

A popular hypothesis for the cognitive benefits of mind-body practices such as yoga is that the improvement in cognition is a consequent function of downregulation of the HPA axis activity. As previously mentioned, an increase in stress leads to secretion of cortisol via hyperactivity of the HPA axis, and an increase in cortisol is associated with a detrimental effect on cognitive functioning.

In order to test this hypothesis, studies have examined whether yoga can affect the HPA axis, by measuring markers of HPA axis activity, primarily cortisol. Vera (2009) examined cortisol and dehydroepiandrosterone (DHEA) levels among yoga practitioners (vs. controls) that had been doing Sivananda yoga 2 times/week for 60 minutes, for the last 3 years. Yoga practitioners showed a higher level of cortisol, better sleep quality, and no difference in DHEA level as compared to controls. In another study, cortisol decreased similarly for both the yoga and control groups (Schell, Allolio, & Schonecke, 1994). Among full time working employees experiencing stress, a 16-week kundalini yoga program resulted in a significant decrease in noradrenaline level post-intervention, but this was not different from the group undergoing cognitive behavioral therapy. No changes were observed in the level of adrenaline and cortisol (Granath, Ingvarsson, von Thiele, & Lundberg, 2006).

In contrast, serum cortisol decreased after a 50-minute yoga practice among eight yoga practitioners. This change was negatively correlated with percent alpha time thus implying an overall relaxed state, but was not associated with other waves (Kamei et al., 2000). In a non-randomized study comparing participants engaging in African dance vs. yoga vs. attending a lecture for 2 hours, participants in the yoga and dance group showed a reduction in perceived stress and negative affect at the end of the session. Participants in the yoga group showed a decrease in serum cortisol levels after the session (West, Otte, Geher, Johnson, & Mohr, 2004). Similarly, cortisol secretion and concentration reduced after a 90 minute session of ‘Yoga stretching’ which did not include breathing exercises and meditation, among older women (Edaet al., 2018).

Pascoe & Bauer (2015) conducted a systematic review of RCTs examining the impact of yoga on physiological outcomes of stress in populations that were healthy or with a neurological or physiological disease. Up until 2014, 13 RCTs had measured the relationship between yoga and cortisol, and most of the studies showed a decrease in cortisol levels after engaging in a yoga intervention. Greater engagement in yoga in terms of duration + frequency resulted in a higher improvement in biological markers of stress, such as blood pressure, cortisol and interleukin. However, all of these were Hatha yoga practices of a similar intensity. Overall, the impact on HPA and PNS activity was more prominent in diseased rather than healthy adults. When comparing different styles of yoga with hatha yoga, results indicated that hatha yoga had a better impact on HPA and PNS activity than Iyengar or restorative yoga. However, the authors clarified that there were too few studies examining different types of yoga and the results were inconsistent to draw clear conclusions. Similarly, there weren’t enough studies examining the effectiveness of different components of yoga.

While these studies only addressed whether yoga affects markers of HPA axis, Gothe, Keswani, & McAuley (2016) conducted one of the first RCTs examining whether cortisol is the pathway through which yoga affects cognition. Older adults (n = 118) either participated in 8 weeks of Hatha yoga involving postures, breathing exercises and meditation, 3 times/week for 60 minutes or performed stretching exercises for the same amount of time. While there was no difference between cortisol levels in the two groups after 8 weeks, the yoga group showed an attenuated effect on their cortisol when exposed to a stressor, as compared to the control group. This effect was predictive of higher performance on the cognitive tasks in the yoga group, hence showing support for the hypothesis that a reduction in cortisol may be the pathway to cognitive improvement after engaging in yoga. They recommended future research to examine other hypothesized mechanisms for this relationship, such as an increase in parasympathetic activity.

Effects on autonomic nervous system

PNS, often known as the 'rest and digest' system, conserves energy by reducing heart rate, and increases the intestinal and gland activity, in opposition to the sympathetic nervous system which is implicated in the 'fight or flight' response. Heart rate variability (HRV) is commonly used as a measure of the balance between sympathetic and parasympathetic nervous activity. Measures of low frequency (LF) and high frequency (HF) bands/activity are obtained while assessing HRV. High HF and low LF activity, as well as high LF/HF ration is thought to depict dominance of PNS activity over sympathetic activity, albeit equivocally. Some studies have shown a sympathetic dominance (increase in low frequency HRV and/or decrease in high frequency HRV) during tasks that are mentally stressful (Hjortskov et al., 2004; Moriguchi et al., 1992; Sloan, Korten, & Myers, 1991), or better performance on executive function tasks in case of PNS dominance (Backs & Seljos, 1994; Hansen, Johnsen, & Thayer, 2003; Matthews, Paulus, Simmons, Nelesen, & Dimsdale, 2004; Nonogaki, Umegaki, Makino, Suzuki, & Kuzuya, 2017; Thayer, Hansen, Saus-Rose, & Johnsen, 2009) that is stronger after aerobic exercise (Albinet, Boucard, Bouquet, & Audiffren, 2010; Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004). On the other hand, some other studies have shown a lack of association (Garde, Laursen, Jørgensen, & Jensen, 2002; Hoshikawa & Yamamoto, 1997; Wahlström, Hagberg, Johnson, Svensson, &

Rempel, 2002). Presence of stress and anxiety has also been linked to poor cognitive function. Thus, it has been hypothesized that the effect of yoga on cognition may be through a dominance of PNS activity over sympathetic activity.

Non-randomized studies (Papp, Lindfors, Storck, & Wändell, 2013; Patil, Mullur, Khodnapur, Dhanakshirur, & Aithala, 2013; Vinay, Venkatesh, & Ambarish, 2016) and randomized control trials (Satyapriya, Nagendra, Nagarathna, & Padmalatha, 2009; Sawane & Gupta, 2015) have shown an increase in PNS activity among yoga novices following long-term yoga interventions . Studies with long term yoga practitioners have shown a dominance of PNS activity in favor of yoga practitioners, as compared to controls (Khattab, Khattab, Ortak, Richardt, & Bonnemeier, 2007; Muralikrishnan, Balakrishnan, Balasubramanian, & Visnegarawla, 2012). In long-term studies that focus only on breathing, positive effects on PNS have been observed (R. P. Brown & Gerbarg, 2009; Pal & Velkumary, 2004; Santaella et al., 2011; Sinha, Deepak, & Gusain, 2013; Telles, Nagarathna, & Nagendra, 1994). In acute studies, the intensity of breathing (slow or fast) seems to determine whether there is an increase in PNS activity or sympathetic activity (Cysarz & Büssing, 2005; Peng et al., 2004; Raghuraj, Ramakrishnan, Nagendra, & Telles, 1998; Santaella et al., 2011; Selvaraj et al., 2008; Telles, Singh, & Balkrishna, 2011).

Most of these studies have primarily focused on a single aspect of yoga, be it breathing or meditation. More RCTs are needed on long-term yoga practice that includes all three components (i.e. postures, breathing, and meditation), and how it relates to cognitive functioning (Nagendra et al., 2015), along with large sample sizes (Tyagi & Cohen, 2016).

Another potential mechanism is the role of Gamma Aminobutyric Acid (GABA), which is a neurotransmitter that is implicated in those with depression, anxiety or mood disorders, and adults with these disorders exhibit lower levels of GABA as compared to health controls. Across two studies with health adults and yoga practitioners, Streeter found an increase in the level of GABA following an acute session of yoga (Streeter et al., 2007), but not after a 12-week intervention (Streeter et al., 2010). The research with GABA is at a very preliminary stage and more research is needed to understand its role in yoga-dependent effects.

In conclusion, of the three mechanisms discussed above, the potential mechanism of HPA axis has higher quality research, in terms of the number of RCTs, and sample sizes. Additionally, it also has more studies that involve all three components of yoga (postures, breathing, and meditation) as compared to studies involving isolated components. Studies have shown mixed evidence for whether yoga affects cortisol, with more specific analysis such as comparison of types of yoga not being possible due to a small number of studies. While studies measuring the effect of yoga on physiological measures of stress explored the dose-response in terms of duration and frequency, none of the studies measured whether a yoga intervention of a higher intensity may have an effect on stress. The next section describes preliminary data of an acute yoga study, focusing on sun salutation, which is a flow-based, dynamic, and low-to-moderate intensity form of yoga, on executive functioning and psychosocial measures of stress.

Preliminary data - sun salutation, relaxation, and aerobic exercise

A pilot RCT was conducted to test the acute effects of sun salutation on cognitive and psychological responses relative to aerobic exercise and an attention-control condition. Participants were adults between the ages of 18 and 45 years, who were experiencing at least three of six stress symptoms from the checklist of Generalized Anxiety Disorder for the last six months, and had not engaged in physical activity, yoga, or similar activities more than twice per week in the last three months. They were randomly assigned to either one 30-minute session of yoga (n = 25), aerobic treadmill walking (n = 22), or a video-viewing condition (n = 24). Participants in the yoga group engaged in sun salutation through a YouTube video displayed on a portable tablet. The video instructed participants through 12 rounds of sun salutation, progressively increasing the pace of the sequence, along with breathing exercises after every four sequences. Participants in the aerobic exercise group walked on a treadmill at a moderate intensity, i.e. between 55-70% of their heart rate maximum and those in the attentional control group watched an educational video by Dr. Andrew Weil on healthy eating. A research assistant was present at all times to supervise the participants and suggest modifications (for the yoga group). Before and after the intervention, participants answered psychosocial questionnaires and completed cognitive assessments.

Participants were mostly female (87.3 %), young adults (M_{age}=27.84 years [*SD* = 8.85]; range 18 to 45 years), Caucasian (56.3%; 23.9% Asian, and 11.3% African American) and non-Hispanic (88.7%). Most participants (33.8%) had attended some college, 26.8% had a college degree, 26.8% had an advanced degree, and 12.7% were high school graduates. 46.5% of participants had an annual household income >$100,000, and most of the participants were never married (77.5%). On average, participants had exercised previously for three to six months. 71.8% had previously engaged in yoga, on average, for one to three months. Only 9.9% had practiced yoga for longer than six months. Most participants (60.6%) had never engaged in other mind-body practices such as Tai-chi. At baseline, participants had a moderate level of perceived stress (*M*= 21.47, *SD*=6.36; maximum score of 40). The mean score for anxiety was 9.35 (*SD* = 4.37, borderline anxiety), and the mean score for depression was 7.14 (*SD* = 3.79, normal), assessed by the *Hospital Depression and Anxiety Scale*. The average self-efficacy for performingyoga, including postures, breathing, and meditation, was 68% (*SD* = 20.80, range =

0-100%). The composite physical activity score measured by *Godin Leisure Time Exercise Questionnaire* was 20 (*SD* = 20.85, maximum score of 99), indicating that participants were low active. The majority were overweight according to body mass index (*M* = 26.35, *SD* = 7.26) and according to current American Heart Association guidelines, 45.1% were prehypertensive (*M*=121.30 / 91.18mmHg). The full sample's mean systolic blood pressure was 110.76 mmHg and their meandiastolic blood pressure was 81.14 mmHg.

Intervention evaluation

Participants in the yoga group answered a survey post-assessment evaluating the yoga intervention. 68% (17 of 25) liked the video instruction. Participants found the video clear and understandable (*M* = 6.08 [*SD* = 1.18]; 1 = strongly disagree and 7 = strongly agree), easy to follow (*M* = 5.88; *SD* = 1.30), and easy to learn the poses through the video (*M* = 5.48; *SD* = 1.45). They also reported a high likelihood of using yoga videos in the future to practice yoga at home (*M* = 6.04; *SD* = 1.43). The majority (72%) of participants liked the pace of sun salutation, while the rest would have preferred a slightly slower pace. Participants rated the pace of the sequences between 'somewhat fast' and 'neither fast nor slow,' and the difficulty level of the poses as 'neither difficult nor easy.' All participants responded that they would recommend this intervention to their family and friends. 92% said that they would choose to do sun salutation as a long-term physical activity performed 3 times/week, and all participants responded that they would be willing to participate in an 8-week sun salutation intervention. The intervention was adequately challenging, liked by most participants, and was an activity that participants would like to engage in in the future.

Fidelity check

There was a significant difference in post-session heart rate between all three groups (p <

.05). The yoga group had a mean HR of 100.24 (*SD* = 14.40), the walking group had a mean HR of 119.27 (*SD*=6.54), and the control group had a mean of 69.63 (*SD*=8.41). All groups differed significantly in their focus of attention ($p < .05$, $\eta_p^2 = .48$) with the yoga group having the most internally-oriented focus of attention (*M* = 7.84 [*SD* = 1.74]; range: 1 = external, 10 = internal), relative to the aerobic exercise group (*M* = 2.73; *SD* = 1.48) and the control group (*M* = 5.44; *SD* = 3.01). There was a significant difference between the two exercise groups in the rating of perceived exertion (6 = very very light, 19 = very very hard) and the control group (*M* = 7.63; *SD* = 2.39), but not between the yoga (*M* = 11.24; *SD* = 2.16) and aerobic exercise group (*M* = 11.73; *SD* = 2.14), as expected.

Cognitive changes

All analyses (repeated measures analysis of covariance) accounted for the pre-intervention score, baseline stress, cardiorespiratory fitness, and education. A Repeated Measures analysis of covariance (ANCOVA), controlling for baseline stress, estimated cardiorespiratory fitness, and education, was conducted for n-back. There were no significant differences, with very small effect sizes ($\eta^2 < .025$) for reaction time and accuracy for 1-back non-match and 2-back match. For 2-back non match reaction time (hardest condition), there was a small effect size but the difference was not statistically significant [F (2,65) = .82, $p = .23$, $\eta_p^2 = .03$]. There were no significant group differences on TMT-A. There were no significant group differences on TMT-B (the more complex task), but there was a small effect size [F (2,67) = 1.43, $p = .24$, $\eta_p^2 = .04$]. The yoga group and aerobic exercise group had similar reduction in time taken to complete the task from pre-intervention to post, which was higher than the control group. All groups improved in their performance on the digit symbol substitution test measuring processing speed, with no significant differences between groups. The null result on n-back may be attributed to the difficulty level of the task. Previous studies have found significant differences with the shapeversion of n-back (Gothe et al., 2013) but not with the letter version used in the present study (Bowden, Gaudry, An, & Gruzelier, 2012). Although different variants of n-back broadly activate the same brain regions, there are minute distinctions in brain activation based on stimulus type. Verbal stimuli were associated with increased activation in the left ventrolateral prefrontal cortex that is responsible for language and speech (Nystrom et al., 2000; Owen, McMillan, Laird, & Bullmore, 2005), which may provide an opportunity to re-organize material and aid in its monitoring or manipulation. In contrast, there was no left ventrolateral prefrontal activation for non-verbal stimuli (Owen et al., 2005), and the shapes task was more difficult at higher levels of the task (Nystrom et al., 2000). Engaging in yoga may be insufficient for activating or augmenting language processing, as the focus during this activity is on quieting the mind and paying attention to body movements and breath. Few acute yoga studies measuring cognitive aspects have been conducted, with equivocal results owing to differences in the duration, type, and intensity of the yoga sessions, suggesting the need for more studies (Gothe etal., 2013; Luu & Hall, 2016).

Psychosocial changes

A univariate ANOVA showed a significant group difference for state anxiety with a moderate effect size [F (2,67) = 4.93, $p < .05$, $\eta_p^2 = .13$], after controlling for the pre-intervention score. Post-hoc Bonferroni tests showed that yoga group had the lowest anxiety post-intervention (M = 30.04, SD = 7.00), which was significantly different than the aerobic exercise group (M = 35.95, SD = 8.93), and the control group (M = 36.00; SD = 9.24). There was almost a significant group difference in the stress visual analogue scale, with a moderate effect size (p = .05, η_p^2 = .09). The yoga group reported the lowest score for stress post-intervention (M = 21.08; SD =

17.22), followed by the aerobic exercise group (*M* = 28.82; *SD* = 25.56), and the control group (*M* = 38.21; *SD* = 22.39). Similarly, with respect to the Feeling Scale (ranging from -5 [very bad] to + 5 [very good]), there was a non-significant, small-to-medium effect, with the yoga group reporting higher pleasant feelings as compared to the aerobic exercise group (*Ms [SDs]* = 3.68 [1.07] vs 2.55 [1.26], $p = .05$). This is similar to previous literature that has shown reductions in stress and anxiety following acute and long-term yoga interventions. Specifically, anxiety reduced post-intervention after engaging in six minutes of sun salutation daily for four weeks, measured by the *General Health Questionnaire*. Other studies have shown reductions in self-reported stress and anxiety, as compared to a true control group, after an acute session of low-intensity yoga (Huang et al., 2013; Melville, Chang, Colagiuri, Marshall, & Cheema, 2012). Participants in the yoga group reported a significantly higher level of absorption and flow during the intervention with a moderate effect size, as compared to the control group. Additionally, the yoga group had significantly higher self-efficacy for yoga postures post-intervention, with a moderate effect size, as compared to the aerobic exercise group (*Ms [SDs]* = 73% [17.16] vs 63% [17.05]). Few studies have examined changes in yoga self-efficacy post-intervention, and none of them have measured changes following an acute intervention. Some of the longitudinal yoga studies have found evidence of improvement in self-efficacy post-intervention (Mehta & Sharma, 2011; M. Sharma, 2001).

Conclusion

Overall, results support a favorable psychosocial profile for the yoga group. The yoga group had an internal focus of attention, and showed significantly higher absorption and flow during the activity compared to the control group, higher self-efficacy than the aerobic exercise group, and more reduction in self-reported stress and anxiety as compared to both groups. An improvement favoring both physical activity groups (vs. control) was observed in one test of executive functioning measuring global cognition, whereas all three groups improved in other tests. A long-term sun salutation RCT assessing changes in executive functioning and psychosocial variables will provide further insight into the impact of yoga on these constructs.

Chapter III: METHODOLOGY

Recruitment

The study involved a targeted recruitment of low-active full-time working adults, between the ages of 18 and 64 years, from the Champaign-Urbana area to participate in a physical activity intervention for eight weeks. Low active participants, i.e. those engaging in less than 3 days/week of physical activity for at least 30 minutes, were recruited. Full-time working adults were defined as those working for > 35 hours/week and currently not enrolled as a student in the University. Recruitment was conducted through email listservs sent out to the University employees, locally-displayed flyers in popular community gathering spots (e.g., cafes, libraries), and via cold calls and emails to database contacts (individuals who previously expressed interest in future studies). The study was advertised as an opportunity to engage in a transitional physical activity intervention that will begin with supervised physical activity, 3 times/week, for two weeks, followed by partially supervised and unsupervised activity for three weeks each. The entire program lasted eight weeks. Online and paper advertisements directed participants to complete a brief interest survey which collected contact information, and offered a self-assessment of preliminary eligibility criteria (required inclusionary demographics). Prospective participants were given the option to contact the research staff by phone or email. Upon receipt of completed interest surveys, prospective participants were contacted by a staff member to set up a time for a screening call lasting approximately 15 minutes. All information collected during screening was stored on a secure Microsoft Access Database accessible only to the investigative team. Upon passing the initial eligibility criteria, participants were required to sign an electronic informed consent document (ICD) to participate in the study.

Inclusion and exclusion criteria

Detailed inclusion and exclusion criteria are presented in Table 1. Inclusion criteria regarding mobility has been included to ensure that participants will be able to engage in aerobic activity and all yoga movements, and will have a low risk of injury when practicing at home. Additionally, no prior knowledge of yoga is required.

Experimental design

The present study was registered as a clinical trial (NCT number here). This study was a two-armed, home-based physical activity intervention designed for full-time working adults showing symptoms of stress or anxiety. The physical activity intervention lasted eight weeks, along with 2 weeks of pre-intervention and post-intervention testing, totaling 10 weeks. Upon passing the eligibility criteria and signing the informed consent form, participants were randomly assigned to one of two groups for an eight-week intervention. A block-order random number generator was used to randomize participants into one of two groups. One group engaged in yoga for a duration of 50-55 minutes every session, 3 times/week. The yoga intervention consisted of 40 minutes of sun salutation and 10-15 minutes of breathing and relaxation. The other group was a waitlist control group, engaging in their regular activities during the 8-week intervention. They were provided videos from the intervention after they completed the study.

During the partially supervised and unsupervised sessions, the yoga group was contacted via email at the end of the week, to ask about their progress, to remind participants to plan and set aside times that they will engage in the intervention, the potential times that they will perform their sessions, and inquire about any issues they are having with the intervention. All participants scheduled one online appointment (~1.5 hours) to partake in pre-intervention testing, and one appointment for post-testing.

Intervention group

The intervention consisted of participants engaging in a progressive series of sun salutation with flow movements, along with breathing and relaxation, for a period of eight weeks. The intervention was titrated in terms of supervision, with all sessions in the first two weeks being completely supervised, followed by one supervised session for the next three weeks, and lastly, three weeks of unsupervised sessions. All classes were conducted online through Zoom, which is a live video interaction platform. Zoom was been chosen because of the features of this application. It allowed the video of the instructor to share maximum screen space, without toggling to other participants' video. Participants were muted, but were able to unmute themselves in case they have questions, and were able to chat. All classes had, at maximum, 10 participants at one time. Classes were be led by a trained and certified yoga instructor, and designed by a trained yoga teacher and practitioner. Since participants were new to the activity, an orientation to the activity was provided by conducting three classes during the first week as one-on-one classes instead of the group class. During these orientation classes, the instructor provided extensive feedback to participants about their body alignment and movements, and explained the features of the application. Following the orientation classes, all classes were conducted in a group format. For the first two weeks, participants performed basic sun salutation of hatha yoga while increasing the speed gradually, and deep breathing. In week three, flow movements were added to the basic sequence of sun salutation. These movements included raising hands upwards and bending down for forward toe touch, spinal twist in the lunge position, leg movements in the downward dog position, and repeating these movement five times in each sequence. Ocean breathing and alternate-nostril breathing were introduced. In week four flow movement sequence, sun salutation basic with flow movements, and sun salutation A were performed. Humming bee breathing was introduced. In week 5, participants performed sun salutation A with flow movements, and sun salutation B. The flow movements in weeks four and five included triangle pose, cat-cow pose, child's pose, boat pose, thunderbolt pose, sitting toe touch, spinal twist that were linked together to form a sequence. In week six, participants performed sun salutation basic, sun salutation A, sun salutation B with flow movements that included raising up and bending forward, triangle pose, and spinal twist during the warrior pose sequence of sun salutation B. In week seven, participants performed sun salutation basic, sun salutation A, sun salutation B with different flow movements that included leg movements during downward dog, extended triangle pose, and spinal twist during the warrior pose sequence of sun salutation B. In week eight, participants performed sun salutation basic, sun salutation A with flow movements from week four, and sun salutation B with flow movements.

In weeks three, four, and five, participants attended the instructor led classes as the first session of the week. In weeks six, seven and eight, participants practiced entirely on their own. A video was provided to participants to aid their unsupervised sessions. At the beginning and end of each session, participants immediately measured their heart rate on Fitbit, and filled out a brief survey (< 2 minutes) that included reporting their heart rate, rating of perceived exertion, stress visual analogue scale, focus of attention, and affect.

Waitlist control group

The waitlist control group was not provided with an intervention during the course of the study. They were asked to carry on their regular activities and refrain from starting new activities, such as regular exercise. After they completed the study, they were provided with the material used in the yoga intervention. See Figure 4 for the study timeline.

Primary and secondary aims

The primary aim of the study was to improve executive functioning of full-time working adults facing symptoms of stress, following participation in yoga. It was hypothesized that participants engaging in yoga would show significantly better performance on tasks assessing executive functions, as compared to the waitlist control group. Secondary aims included a reduction in general and job-related stress and anxiety, testing the hypothesized mediation between stress and executive functioning, and improvement in psychosocial measures, and cardiorespiratory fitness. It was hypothesized that participants engaging in yoga would show better psychosocial outcomes.

Measures

Demographics. Participants completed a baseline survey about their demographic information, including age, sex, educational status, employment status, socioeconomic status, health insurance, health history and yoga and exercise history.

Biometrics. Participants self-reported their height and weight.

Cardiorespiratory fitness. This was estimated using the Cardiorespiratory Fitness Questionnaire. Participants were asked to report their usual level of aerobic physical activity, and got a score ranging from one (no activity) to five (highly active). They also reported on their age, sex, resting heart rate, height, and weight. A total score was calculated based on all the above parameters, and ranged between 1 (low fitness) and 3 (high fitness).

Neuropsychological assessments

Neuropsychological assessments were completed remotely at baseline and post-intervention (week 9). Some of the tests were administered via Psytoolkit, which runs the tests on participants' personal desktop or laptop. The technological requirements required to run Psytoolkit were confirmed during screening with each participant. The other tests were conducted via a Google Meet (GM) call. The GM call was continued when participants were doing tasks on Psytoolkit as well, to ensure that any issue faced by the participant was resolved and the assessment ran smoothly.

Psytoolkit tasks

Stroop task: Stroop task measures response inhibition or response interference control. Participants were shown a series of word colors that were either congruent or incongruent with the color of the word itself. Participant were asked to respond to the color of the word and not the word itself. Responses were made with the keyboard. The incongruent condition was the more difficult condition of the two. Reaction time was recorded and a cost score was calculated, with shorter cost scores indicating better performance.

Task switching paradigm: This measures cognitive flexibility, i.e., a participant's ability to adapt quickly to changing rules and the cost associated with it. In this task, participants had to characterize the picture presented according to shape or color, with a switch in the rules occurring every two tasks. Participants were cued to the rule before the stimulus was presented. Reaction time and accuracy were recorded, with lower reaction time and higher accuracy indicating better performance. Participants completed 40 trials.

Tasks administered via GM call.

Digit span forward and backward: This is a measure of the storage and manipulation capacity of working memory. The participant was shown a series of digits presented on PowerPoint, through screen sharing. The minimum length of digits presented was 3 (e.g., 638) and the maximum length was 9 (e.g., 628295702). In the forward task, participants were asked to recall the digits exactly as they were presented, while in the backward task, they had to recall them in the reverse order. Digit-span backward was the more complex task of the two. Accuracy was recorded, with higher accuracy indicating better performance.

Digit symbol substitution test (DSST): DSST is a task measuring processing speed. Participants were shown a code-key in which every digit matches a particular symbol. Then, they were shown a symbol on the screen and participants had to say the corresponding digit aloud, as quickly and accurately as possible. Participants were given 90 seconds to complete as many digit-symbol pairings as possible. The number of accurate pairings were recorded, with a higher score indicating better performance. This task will be completed by showing the symbols to participants via screen sharing.

Psychosocial assessments

Perceived stress. The Perceived Stress Scale (PSS), developed by Cohen, Kamarck, and Mermelstein (1983) was used to measure perceived psychosocial stress. The PSS is a 10-item scale that measures the extent to which situations are perceived as stressful, and includes questions such as "In the last month, how often have you been upset because of something that happened unexpectedly?" Responses ranged from 0 (Never) to 4 (Very often). Total score was calculated by summing all items after reverse coding for certain items. Higher scores indicated a higher level of perceived stress.

The Brief Job Stress Questionnaire, developed by Kawada and Otsuka (2011) , is a 15-item scale measuring job stress. It focuses on the evaluation of job demands, job control, job support, and degree of job satisfaction. Responses were scored on a 4-point Likert-type scale, where 1 = agree and 4 = disagree. Total score was calculated by summing all items after reverse coding for certain items. Higher scores indicated a lower level of job stress.

The Visual Analogue Scale for stress is a one-item measure asking participants to rate their perceived stress in the moment, on an unmarked ruler with endpoints labelled 'none' and 'as bad as it could be.' It ranged from a score of 0-100, with higher scores indicating a higher level of perceived stress.

Anxiety and depression. The Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983) is a 14-item scale measuring depression and anxiety. It includes questions such as *"I feel tense or wound up"* (depression) and *"I feel restless as if I have to be on the move"* (anxiety). Responses ranged from 0-3 on a Likert type rating scale. Total score was calculated by summing responses on seven items measuring depression, and seven items measuring anxiety. A total score of 0-7 indicated 'normal', 8-10 indicated 'borderline abnormal', and 11-21 indicated 'abnormal'.

Anxiety. The State Trait Anxiety Inventory (STAI; (Spielberger, 2010) is a 40-item scale which measures state and trait anxiety (20 items each). Responses were scored on a Likert type scale ranging from 1 (almost never) to 4 (almost always). A total score was calculated for each subscale by summing the items (after some required reverse-coding). Higher score indicated a higher level of anxiety.

Self-efficacy. Self-efficacy specific to yoga was assessed using the *Yoga Self-efficacy Scale* (Birdee, Sohl, & Wallston, 2016). It is a 12-item scale that measures self-efficacy related to engaging in yoga postures, breathing, and meditation. Responses were scored on a Likert type scale ranging from 1 (strongly disagree) to 9 (strongly agree). The response options of the scale was modified to percentages (0% to 100%). Total score was calculated by summing all items, and higher score reflected higher self-efficacy. Additionally, a total score was calculated separately for questions relating to postures, breathing, and meditation.

Self-efficacy to engage in physical activity was assessed using the *Lifestyle Self-efficacy Scale* (McAuley et al., 2009), which asked participants about their belief in their ability to be physically active five or more times per week at a moderate intensity, for at least 30 minutes, for six months. The duration was modified to reflect the duration of the study, i.e., 8 weeks. Responses ranged from 0% (not confident at all) to 100% (highly confident). The total score was calculated by averaging the response for all items, with higher scores reflecting higher self-efficacy to engage in physical activity for eight weeks.

Self-efficacy to engage in physical activity in the face of barriers was assessed using four items from the *Barriers-specific Self-efficacy scale (BARSE).* Participants rated their confidence to regularly engage in physical activity in bad weather, while on vacation, without encouragement, and when under personal stress, from 0% (not confident at all) to 100% (highly confident).

Mindfulness and attention. Mindfulness was assessed via the *Mindfulness and Attention Awareness Scale* (K. Brown & Ryan, 2003). It is a 15-item measure of dispositional mindfulness in the context of day-to-day activities. Participants answered on a Likert type response scale ranging from 1 (almost always) to 6 (almost never). The total score was calculated by summing the response to all items, and higher scores reflected a higher level of dispositional mindfulness.

Self-compassion. Self-compassion was assessed via the *Self-Compassion Scale* (Neff, 2003). It is a 26-item measure of self-compassion, with items across six subscales, namely, self-kindness, self-judgment, common humanity, isolation, mindfulness, and over- identification. Participants answered on a Likert type response scale ranging from 1 (almost never) to 5 (almost always). A total score of general self-compassion was derived by summingall the items.

Positive and negative affect schedule (PANAS). The PANAS (Watson, Clark, & Tellegen, 1988) is a 20-item scale measuring positive and negative feeling states over the past week. Each scale has 10 adjectives describing feelings, and responses range from 1 (Very slightly or not at all) to 5 (Extremely). A total score was calculated by summing items in each subscale after reverse coding few items, and a higher score indicated higher positive or negative affect.

Questionnaire for the assessment of personal optimism and social optimism—extended (POSO-E): Personal optimism and self-efficacy optimism from the POSO-E (Gavrilov-Jerković, Jovanović, Žuljević, & Brdarić, 2014) will be measured. This is a 9-item scale has descriptive statements regarding optimism, and participants rate whether the statement describes them on a 4-point Likert scale, ranging from 0 (completely incorrect) to 3 (completely correct). A total score was calculated by averaging the response for each subscale, with higher scores indicating higher optimism.

Experienced bodily changes scale (EBCS). The EBCS (O'Connor, Rousseau, & Maki, 2004) is an 8-item scale that measures perceived physical changes such as changes in energy level, body weight, and physical appearance. Responses are scored on a 11-point Likert type scale ranging from -5 to +5, wherein 0 means 'no change,' + numbers mean improvement, and – numbers mean deterioration. Mullen (2011) found that the 8-item scale was not unidimensional and proposed a four-item version measuring physiological change, which was used. Additionally, five questions were added to measure changes related to other relevant dimensions such as energy level, stress, and mindfulness. These have previously been used in adissertation study with internal reliability of .77 (J. D. Cohen, 2019).

Physical activity. Physical activity at baseline was assessed via the *Godin-Shephard*

Leisure-Time Physical Activity Questionnaire (GLTEQ) (Gaston Godin, 2011). The GLTEQ assesses leisure-time activity across three modes of activity: strenuous, moderate, and mild, in terms of frequency and duration. Weekly frequencies of strenuous, moderate, and mild activitieswere multiplied by nine, five, and three, respectively to create the total score or number of units.According to this score, 24 units or more is indicative of an active individual, whereas any scorebelow 24 is indicative of a non-active individual.

Outcome expectations. Participants' expectations about the outcomes of this intervention were assessed using the Multidimensional Outcome Expectancies for Exercise Scale (MOEES). It is a 15-item questionnaire measuring physical outcome expectancies, social outcome expectancies, and self-evaluative outcome expectancies. Responses range from 1 (strongly disagree) to 5 (strongly agree). The total score for each subscale was calculated by summing the items, with higher scores being indicative of higher outcome expectations for exercise.

Self-regulation. The *Physical Activity Self-Regulation Scale* (PASR-12) (M. R. Umstattd, Motl, Wilcox, Saunders, & Watford, 2009) was used to assess the use of self-regulation strategies for engaging in physical activity. The PASR-12 is a 12-item questionnaire with responses ranging from 1 (never) to 5 (very often). A total score was calculated by summing up responses to all the items. There are also six subscales (self-monitoring, goal-setting, social support, reinforcement, time management, and relapse prevention), however, research by our lab found that this scale is not uni-dimensional. We will use a modified version of the scale. Higher score reflects higher use of self-regulation strategies.

Pain. Bodily pain was assessed using the 2-item bodily pain subscale of Short Form-36 (Håvard Loge & Kaasa, 1998), and the Pain Visual Analogue Scale. The questions are *"How* *much bodily pain have you had during the past 4 weeks?"* with responses ranging from none to very severe, and *"During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?"* with responses ranging from not at all to extremely. The total score was calculated by averaging the response to these two items, and a higher score reflected lesser pain. Pain Visual Analogue Scale is a one-item measure asking participants to rate their perceived pain in the moment, on 10-point ruler with labels of 'no pain' (0), 'moderate pain' (5) and 'worst pain' (10). Higher scores indicated a higher level of perceived pain.

Rating of perceived exertion (RPE). Participants will be asked to rate their perceived exertion after engaging in the exercise session. The modified RPE scale (Borg, 1998) is a 10-point scale ranging from 1 (no exertion at all) to 10 (maximal exertion) and it measures the perceived intensity of the exercise. It has been validated with objective measures of physical activity intensity (Day, McGuigan, Brice, & Foster, 2004; Noble, Borg, Jacobs, Ceci, & Kaiser,1983; Pincivero & Timmons, 2010).

Focus of attention. Participants will be asked to rate their focus on attention via the item *"During the last exercise session, where was your focus of attention?"* The response ranged from 0 (external focus of attention) to 10 (internal focus of attention). This item was validated (Hutchinson & Tenenbaum, 2007) and was previously used to understand mental states in mind-body interventions (Phansikar et al., 2018).

Affect. Participants rated their affect on the Feeling Scale (Hardy & Rejeski, 1989), ranging from 5 (very good) to -5 (very bad), with 0 meaning neutral.

Heart rate. Participants measured their heart rate before and after the exercise session, using Fitbit. Fitbit calculates heart rate using photoplethysmography, which is the same technology used in a pulse oximeter. This technology detects fingertip pulse by using the smartphone's built-in camera to emit light and track color changes on the fingertip that are directly linked to one's pulse. Heart rate measurement using Fitbit based on photoplethysmography has been validated (Bai, Hibbing, Mantis, & Welk, 2018).

Anxiety and depression, mindfulness, perceived stress, positive affect, self-compassion, self-efficacy, and self-regulation were also measured at the mid-point of the intervention (end of week four). All measures are listed in Table 2.

Data analytic plan

Quality control and checking

Online survey data was collected through Qualtrics, downloaded and imported into SPSS version 27 (IBM Corp, Armonk, NY). Data was manually inspected by trained research assistants to verify that importation procedures were successful. Data collected from the neuropsychological tests was imported into SPSS v27. Descriptive and frequency statistics was generated for all variables in order to check for missingness, erroneous data, and outliers. Outliers were winsorized (e.g., replaced by a $\pm$ 2.5 standard deviation calculated value). Missing data was imputed using Expectation-maximization (EM) algorithm to produce unbiased estimates. Composite files were created for all questionnaire data based upon the scoring instructions for each questionnaire. Violations of basic statistical assumptions were examined. Once questionnaire data was submitted online, it was checked for completeness. All data was saved to and processed on a secure, password-protected computer network.

Statistical analyses

All data was analyzed with intention to treat. Three participants did not complete post-testing assessments, and data for them was imputed using multiple imputation with expected maximum likelihood. All descriptive statistics are reported as mean ± standard deviation.

Baseline group comparisons for demographic variables were conducted using t-tests. Baseline group comparisons on demographic variables were carried out using paired *t* tests. To test the first hypothesis, a 2 (Group) x 2 (Time) repeated measures analysis of covariance (ANCOVA) was conducted to identify differences in executive functioning between the two groups from baseline to the 8-week follow-up, whereby a *p*-value of 0.05 or less determined statistically significant inferences. Partial eta squared values were used to determine the magnitude of each effect size. For partial eta squared, 0.01 indicates a small effect size, 0.06 indicates medium, and 0.14 indicates a large effect size. Theoretically relevant and established covariates for analyses involving primary outcomes included education, cardiorespiratory fitness (accounting for age and sex), Fitbit steps, and prior yoga and exercise experience.

To test the second hypothesis, a 2 (Group) x 2 (Time) repeated measures analysis of covariance (ANCOVA) was used to identify differences in psychosocial stress between the two groups from baseline to the 8-week follow-up, whereby a *p*-value of 0.05 or less determined statistically significant inferences. Partial eta squared values were used to determine the magnitude of each effect size. Similarly, differences in other psychosocial secondary outcomes were assessed using ANCOVA. Covariates included cardiorespiratory fitness, prior yoga and exercise experience, and Fitbit steps. Some covariates were be omitted or added to the analysis based upon theoretical relevance.

Path analysis was conducted in Mplus (version 8.1) to test for the mediation effect of stress on digit span backward. Data were assumed to be missing at random and maximum likelihood estimation (ML) was used with bias-corrected bootstrap method (10,000 iterations) for measuring indirect effects and mediation (Fritz, Taylor, & MacKinnon, 2012). Specifically, digit span backward was entered as the dependent variable, which was regressed on stress change from baseline to week 4 (serving the role of mediator). Mediation analysis involves regressions known as *a* path, *b* path, *c* path, and *c'* path. In the *a* path, the mediator is regressed on group. In the *b* path, the dependent variable is regressed on the mediator. In the *c* path, the dependent variable is regressed on group, and in the *c'* path, the dependent variable is regressed on group and the mediator. Stress change was regressed on group, cardiorespiratory fitness, baseline fitbit steps, previous yoga and exercise experience, education, baseline stress, and baseline expectancy of cognitive benefit. Digit span change was regressed on each of the aforementioned. Model fit was assessed using conventional criteria including the chi square ($\chi 2$) statistic, the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA) and the standard root mean square residual (SRMR) (Marsh, Hau, & Wen, 2004). Cut-off values for CFI and TLI $\geq .95$ are preferred for an acceptable model fit, and cut-off values $\leq .06$ for the RMSEA are preferred (Hu & Bentler, 1999; Marsh et al., 2004). We interpreted the effect using a one-tailed significance test and reported the confidence bound. The result was considered statistically significant if the $p < .05$ and the confidence bound was above 0.

CHAPTER IV: RESULTS

Baseline characteristics

Overall, 277 participants expressed interest in the study by completing a brief survey or contacting us via email. 42 contacts were unreachable. Upon screening 235 contacts, 101 met the inclusion criteria and 134 did not. Reasons for exclusion were as follows: physically active (n= 24), low level of stress (n= 21), medical diagnosis of depression (n= 20), lost interest (n= 19), not a full-time employee (n= 17), distance (n= 15), failed PAR-Q (n= 14), unwilling to be randomized (n= 2), unwilling to wear Fitbit (n= 1), and color blind (n= 1). Of the 101 participants meeting the inclusion criteria, 96 signed the informed consent document. Ultimately, 86 participants completed baseline assessments and were randomized to one of two groups (yoga or waitlist control). Two participants officially withdrew from the study for personal reasons unrelated to the study (illness in family, and lack of time), and one participant was lost to follow-up (CONSORT in Figure 5). There were no statistically significant (independent samples t-test) differences between groups across demographics, health history, exercise history, and Fitbit steps, except for annual household income.

Participants were full-time working adults between the ages of 18 and 64, and low-active for at least three months prior to joining the study. The mean age of participants was 41 years. A majority of the participants were female (81.4%), not Hispanic or Latino (91.9%), and married (64%). More than half the participant had an advanced college degree (51.2%), followed by 44.2% with a college degree, 3.5% with some college degree, and 1.2% with a high school degree. With respect to racial identity, 69.8% self-identified as white or Caucasian, 15.1% as Asian, 11.6% as black or African American, and 3.5% was mixed race. 37.2% had an annual household income of >$100,000, followed by 34.9% with an annual income range between

$40,000 to $75,000. There was a significant difference between groups on annual household income, with the waitlist control group having more participants with a higher income than the yoga group.

Participants were full-time working adults, working at least 35 hours per week. Nearly all participants were State Government employees (98.8%), and one participant worked in the private sector. Close to half of the participants (39.5%) identified as "essential workers" who had to report to work during the pandemic. All participants had health insurance, and 75.6% were paid by their employer.

In terms of health history, 3.5% had been diagnosed with cancer, and 4.7% had been diagnosed with diabetes. A majority of the participants did not currently (98.8%) or previously (91.9%) smoke cigarettes, consumed less than one alcoholic drink per day (95.3%), and consumed less than three caffeinated drinks per day (59.3%). More than half of the participants did not restrict consumption of high fat foods (54.7%), did not avoid added sugars (67.4%), and did not keep their body weight within the recommended body mass index range (65.1%). In terms of functional limitations, most participants had no difficulty with seeing (61.6%), hearing (68.6%), walking (96.5%), lifting (94.2%), or remembering and concentrating (61.6%).

In terms of exercise history, about half of the participants (52.3%) had engaged in exercise for at least six months at some point in their life. 48.8% of the participants had between one to 10 years of experience engaging in structured exercise over the course of their lifetime, with an average of 6 months to one year. Our eligibility criteria only included participants who had not engaged in yoga regularly for more than one year, in the last 10 years. This was done to recruit participants with a similar current experience level. Still, it is likely that our participants had experience with yoga at some point in their lives. Over the course of their lifetime, 73.3% of participants had engaged in yoga. Of these, 84.1% had not engaged in yoga for six months or longer over the course of their lifetime, and a majority (55.5%) had less than three months of experience doing yoga. More than half the participants (52.3%) had never engaged in any other mind or mind-body practice such as Tai Chi and meditation. Participants were with overweight, on average, as the mean body mass index was 29.43 (8.13). Participants' average steps derived through Fitbit, at baseline, were 5,934.53 (SD=3,124.16). The mean score on the Godin Leisure-time Exercise Questionnaire was 11.11 (SD=11.18), indicating that participants were low-active at baseline. All means are reported in Table 3.

Feasibility

The total number of participants randomized into the study was 86, with 43 participants in each group. Two participants withdrew from the study. One participant had a family emergency and the other participant did not provide a reason, but reported that they had not been following through with the study and would like to withdraw. One person was lost to follow-up, and later informed us about a family emergency requiring him to leave the country. Eighty-three participants completed the post-testing assessments. One adverse event was reported in the yoga group. The participant reported feeling pain in their upper back, although the source was unknown, it corresponded with a yoga session at which point the pain worsened and caused discomfort in their daily life. The participant did not engage in yoga after the adverse event, but remained in the study and completed follow-up assessments. Another participant from the yoga group injured her hand (unrelated to the study) after a fall down stairs that required subsequent use of a brace. She participant did not engage in any yoga sessions after the injury, but completed post-testing assessments.

The overall attendance rate was 71.3%. After removing participants who dropped out of the study (n = 2) or reported being injured (n = 2), the overall attendance rate increased to 75.1%.This implies that on average, participants attended 2.25 sessions per week. Attendance (four participants removed) was much higher for synchronous supervised sessions led by the instructor(97.15%) as compared to asynchronous self-guided sessions (63.50%). For self-guided sessions, a participant was considered to have engaged in a session if they logged the session on their Fitbit, or completed a log for it. Attendance for each week is reported in Table 4. There was a significant difference in the heart arte recorded after breathing, between supervised and self- guided sessions (p = .006). The mean heart rate after breathing in the supervised sessions was higher (*M*s±*SD* = 81.72±11.14) than self-guided sessions (*M*s±*SD* = 77.26±14.07). There was nostatistical difference in any other variables between supervised and self-guided sessions.

Program enjoyment and evaluation questions were asked only to the yoga group. Overall, all the participants enjoyed the study (70.7% reported yes, 29.3% reported sometimes, and 0% reported no). The total score on the Physical Activity Enjoyment Scale was 38.27 out of a possible score of 56. Most participants (56.5%) sometimes found the study to be a burden on their life, 39% did not find the study to be a burden at all, and 4.9% found it to be a burden. All of the participants would recommend the program to family or friends (75.6% reported yes, 24.4% reported sometimes). A majority of the participants (78%) liked the video instruction for yoga, 17% liked it sometimes, and 4.9% did not like the instruction. Participants rated various aspects of the videos on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). On average, participants found the yoga videos to be clear and understandable [*M* = 6.44 (.95)], easy to follow [*M* = 6.34 (.1.06)], easy to learn the poses through the video [*M* = 6.20 (.1.26)], and would use videos to continue engaging in yoga at home [*M* = 6.24 (1.39)].

In terms of intervention fidelity, the yoga sessions were delivered in the expected manner, as a moderate intensity physical activity, as evidenced by post-session heart rate (HR) measures. Specifically, across all of the sessions, the mean HR was 121.67 (11.16) beats per minute, and on average, was 68.92% of heart rate max. The average rating of perceived exertion (RPE) was 4.03 (1.24), which translates to "sort of hard" on the RPE scale. Heart rates and RPE across the eight weeks are reported in Table 5. Participants reported an internal focus of attention across all the sessions (*M*s±*SD* = 7.65±2.66).

Cognitive assessments

The group x time interaction effect from baseline to 8-week follow-up on digit span forward was close to statistical significance $F(1, 84) = 3.885$, $p = 0.026$, $\eta_p^2 = 0.047$ (see Figure 6). The yoga group had higher accuracy as compared to the control group (*M*s±*SD* = 9.84±1.99 vs. 9.16±2.13). There was a significant group x time interaction effect on digit span backward with a medium effect size $F(1, 84) = 6.621$, $p = 0.012$, $\eta_p^2 = 0.078$. The yoga group had higher accuracy as compared to the control group (*M*s±*SD* = 7.30±3.05 vs. 6.11±2.70). There was no significant group x time interaction effect on digit symbol substitution task $F(1, 84) = .273$, $p = .603$, $\eta_p^2 = 0.003$. There was no significant group x time interaction effect on the Stroop cost score $F(1, 84) = .534$, $p = .467$, $\eta_p^2 = 0.007$. There was no significant group x time interaction effect on the task-switch cost score $F(1, 84) = .040$, $p = .842$, $\eta_p^2 = 0.001$.

Sensitivity analyses were conducted to determine whether attendance and income were predictive of cognitive variables. Attendance and income had a main effect on task-switching cost, but did not have a combined interaction effect after accounting for time. Attendance and income were not significantly related with the other variables. All means are reported in Table 6.

Mediation analysis: Given the model involved the simplest form of A-B-C path analysis and was saturated with all possible paths from covariates, model-to-data fit indices reflected a perfect fit (CFI and TLI = 1.00). The model accounted for 19.70% of the variance in digit span performance. The path estimate (a) representing the effect of group (X) on stress change (M) was statistically significant and supported our hypothesis $\beta = .391$, SE = .089, $p < .001$. The path estimate (b) representing the effect of stress change (M) on digit span (Y) was statistically $\beta = .230$, SE = .120, $p = .027$. The path estimate (c') representing the effect of group (X) on digit span (Y) and stress (M) was statistically significant $\beta = .203$, SE = .112, $p = .034$. Thus, there was partial mediation and the results partially supported our hypothesis (see Figure 7). The direct effect of group on digit span change score was significant $\beta = 0.203$, SE = 0.100, $p = .003$, i.e., the yoga group had higher accuracy on digit span backward task. There was a significant indirect effect of group on digit span performance, via a change in stress from baseline to week four $\beta = 0.090$, SE = 0.053, $p = .045$, $CB = 0.48, \infty$.

Psychosocial assessments

Anxiety and stress

There was a significant group x time interaction effect from baseline to 8-week follow-up on the state-trait anxiety inventory with a medium effect size $F(1, 84) = 5.056$, $p = 0.027$, $\eta_p^2 = 0.059$. The yoga group had significantly lower anxiety post-intervention as compared to the control group (*M*s±*SD* = 34.97±10.34 vs. 39.36±11.96; see Table 7). There was a significant group x time interaction effect on HADS-A with a large effect size $F(1, 84) = 10.304$, $p = 0.002$, $\eta_p^2 = 0.114$. The yoga group had significantly lower anxiety post-intervention, and had a score in the normal range (<7) as compared to the control group (*M*s±*SD* = 6.36±2.95 vs. 8.14±3.75). After accounting for covariates, the effect remained significant. There was a significant group x time interaction effect on HADS-D with a medium effect size $F(1, 84) = 4.360$, $p = 0.040$, $\eta_p^2 = 0.052$. The yoga group had significantly lower depression as compared to the control group

(Ms±SD = 5.74±3.48 vs. 6.31±3.51). After accounting for covariates, the effect remained significant.

There was a significant group x time interaction effect on the stress visual analog scale with alarge effect size $F(1, 84) = 20.850$, $p < .001$, $\eta_p^2 = 0.213$, see Figure 8. The yoga group had significantly lower stress as compared to the control group (Ms±SD = 25.41±20.28 vs. 37.50±24.93). After accounting for covariates, the effect remained significant. There was no significant group x time interaction effect on the Perceived Stress Scale $F(1, 84) = 1.824$, $p = .181$, $\eta_p^2 = 0.022$. However, there was a significant group x time effect from baseline to 4-week follow-up $F(1, 84) = 7.710$, $p = 0.007$, $\eta_p^2 = 0.088$, with the yoga group having lower stress (Ms±SD = 16.77±5.27 vs. 18.68±6.70). There was no significant difference at the 8-week follow-up due to a reduction in the control group's stress score. There was no significant group x time interaction effect on the Brief Job Stress Questionnaire $F(1, 84) = 1.786$, $p = 0.185$, $\eta_p^2 = 0.022$. The yoga group had lower stress scores as compared to the control group. There was a significant group x time interaction effect on the emotion subscale of Covid-related changes with a medium effect size $F(1, 84) = 5.101$, $p = .027$, $\eta_p^2 = 0.062$. The yoga group had a reduction in their score regarding negative emotional changes due to the pandemic, as compared to the control group (Ms±SD = 4.60±1.03 vs. 4.77±1.07). There was no significant group x time interaction effect on the lonely subscale of Covid-related changes with a medium effect size $F(1, 84) = 1.149$, $p = .287$, $\eta_p^2 = 0.145$.

Social cognitive theory constructs

There was a significant group x time interaction effect on total score for yoga self-efficacy with a medium effect size $F(1, 84) = 4.952$, $p = .029$, $\eta_p^2 = 0.059$. Yoga self-efficacy was assessed before and after the 8-week intervention. The yoga group increased in their yoga self-efficacy as compared to the control group, whose mean self-efficacy decline over time (*M*s±*SD* = 74.84±19.38 vs. 62.54±21.32). The group x time effect on subscales of yoga self-efficacy was significant if baseline physical activity was unaccounted for. There was a significant group x time interaction effect on self-efficacy for postures $F(1, 84) = 4.360$, $p = .040$, $\eta_p^2 = 0.052$. There was a significant group x time interaction effect on self-efficacy for breathing $F(1, 84) = 4.581$, $p = .035$, $\eta_p^2 = 0.054$ and meditation $F(1, 84) = 7.710$, $p = .007$, $\eta_p^2 = 0.088$. There was no significant group x time interaction effect on self-efficacy for accumulating physical activity in one's lifestyle $F(1, 84) = .001$, $p = .834$, $\eta_p^2 = 0.001$. There was no significant group x time interaction effect on self-efficacy for overcoming barriers to exercise $F(1, 84) = .874$, $p = .353$, $\eta_p^2 = 0.011$.

There was a significant group x time interaction effect on the total score for physical activity self-regulation with a medium effect size $F(1, 84) = 5.544$, $p = .021$, $\eta_p^2 = 0.066$. The yoga group had significantly higher self-regulation as compared to the control group (*M*s±*SD* = 35.92±7.64 vs. 30.74±8.05). There were no significant difference on the self-monitoring, social support, and reinforcement subscale. There was a significant group x time interaction effect on the goal-setting $F(1, 84) = 5.071$, $p = .027$, $\eta_p^2 = 0.060$, time-management $F(1, 84) = 7.317$, $p = .008$, $\eta_p^2 = 0.085$, and relapse prevention subscale $F(1, 84) = 4.560$, $p = .036$, $\eta_p^2 = 0.055$. The yoga group had higher mean scores as compared to the control group. There were no significant interaction effects on the physical subscale of outcome expectations $F(1, 84) = .211$, $p = .648$, $\eta_p^2 = 0.003$, or the social subscale $F(1, 84) = 2.663$, $p = .107$, $\eta_p^2 = 0.033$. There was a significant group x time interaction effect on the self-evaluative subscale $F(1, 84) = 4.066$, $p = .047$, $\eta_p^2 = 0.049$. The yoga group decreased on their mean score over time.

Positive psychology constructs

These exploratory outcomes have been presented without accounting for family-wise error. Some of the reported outcomes below may be rendered non-significant [statistically] after accounting for all of the number of outcomes being assessed.

There was no significant group x time interaction effect on the mindfulness $F(1, 84) = 3.128$, $p = .081$, $\eta_p^2 = 0.038$. However, there was a significant effect from baseline to 4-week follow up $F(1, 84) = 7.445$, $p = 0.008$, $\eta_p^2 = 0.085$, with the yoga group having higher mindfulness (*M*s±*SD* = 3.68±.83 vs. 3.54±.76).

There was a significant group x time interaction effect on positive affect with a medium effect size $F(1, 84) = 5.015$, $p = .028$, $\eta_p^2 = 0.059$. The yoga group had a higher positive affect as compared to the control group (*M*s±*SD* = 33.07±6.98 vs. 29.57±8.68). After accounting for covariates, the effect remained significant. There was a significant interaction effect on negative affect with a large effect size $F(1, 84) = 13.194$, $p < .001$, $\eta_p^2 = 0.142$. The yoga group had a lower negative affect as compared to the control group (*M*s±*SD* = 17.90±4.30 vs. 20.48±5.86).

There was no interaction effect on optimism $F(1, 84) = .961$, $p = .330$, $\eta_p^2 = 0.012$. However, there was a significant effect from baseline to 4-week follow up $F(1, 84) = 7.135$, $p = 0.009$, $\eta_p^2 = 0.082$, with the yoga group having higher optimism (*M*s±*SD* = 2.38±.54 vs. 2.08±.60).

There was a significant group x time interaction effect on the total score for self-compassion with a large effect size $F(1, 84) = 7.717$, $p = .007$, $\eta_p^2 = 0.088$. The yoga group had higher self-compassion as compared to the control group (*M*s±*SD* = 3.29±.69 vs. 2.98±.68). There was also a significant effect on the self-kindness $F(1, 84) = 7.632$, $p = .007$, $\eta_p^2 = 0.087$ and self judgement subscale $F(1, 84) = 18.926$, $p < .001$, $\eta_p^2 = 0.191$ but not on the other subscales of common humanity, isolation, mindfulness, and over-identification.

There was a significant group x time interaction effect on the MAIA subscales of Not-distracting $F(1, 84) = 6.244$, $p = .015$, $\eta_p^2 = 0.072$, Not-worrying subscale $F(1, 84) = 4.677$, $p = .034$, $\eta_p^2 = 0.055$, Self-regulation $F(1, 84) = 6.499$, $p = .013$, $\eta_p^2 = 0.075$, and Trusting $F(1, 84) = 7.48$, $p = .011$, $\eta_p^2 = 0.078$. There were no significant differences on the Noticing, Attention Regulation, Emotional Awareness, and Body Listening subscales.

Physical activity and function

There was no significant difference in the composite score for Godin Leisure-Time Exercise Questionnaire $F(1, 84) = 1.604$, $p = .209$, $\eta_p^2 = 0.021$. There was a significant difference on the item regarding frequency of engaging in exercise that "works up a sweat" $F(1, 84) = 6.278$, $p = .014$, $\eta_p^2 = 0.076$, with the yoga group having higher frequency ($Ms \pm SD$ = 1.88±1.63 vs. 1.27±1.28).

There was a significant group x time interaction effect on the composite of items measuring perceived physical changes via the perceived bodily changes scale with a medium effect size $F(1, 84) = 6.045$, $p = .016$, $\eta_p^2 = 0.070$. The yoga group perceived more positive change as compared to the control group ($Ms \pm SD$ = .50±.59 vs. -.06±.71). There were no significant changes on the novel items used to assess perceived mental changes $F(1, 84) = .149$, $p = .700$, $\eta_p^2 = 0.002$.

There was no significant difference in the total number of Fitbit steps from week one through week nine, as compared to baseline steps. $F(1, 84) = 2.041$, $p = .157$, $\eta_p^2 = .025$. The yoga group had a higher total number of steps during the intervention as compared to the control group ($Ms \pm SD$ = 59205.54±26483.61 vs. 51367.40±.21861.34)

Differences between engagement in postures and breathing

Our exploratory hypothesis was assessing the unique impact of postures vs. breathing and relaxation on psychosocial outcomes. During each yoga session, participants answered a brief log after engaging in postures, and after engaging in breathing and relaxation. There was a significant difference in heart rate $F(1, 84) = 283.83$, $p < .001$, $\eta_p^2 = 0.77$, with heart rate being higher after postures than breathing (*M*s = 121.67±11.16 and 79.33±12.12) . There was a significant difference in rating of perceived exertion $F(1, 84) = 126.58$, $p < .001$, $\eta_p^2 = 0.60$ with exertion being higher after postures than breathing (*M*s = 4.03±1.24 and 1.29±1.00). There was no significant difference on focus of attention $F(1, 84) = 3.74$, $p = .056$, $\eta_p^2 = 0.04$. The mean score after postures was 8.20 (3.25) and after breathing was 7.11 (1.78). There was a significant difference on the feeling scale with a large effect size $F(1, 84) = 9.14$, $p = .003$, $\eta_p^2 = 0.10$. The mean score was higher after breathing (3.41±1.19) than after postures (2.56±1.40). There was no significant difference on the stress visual analog scale $F(1, 84) = 2.09$, $p = .15$, $\eta_p^2 = 0.02$. The mean score after postures was 20.60 (16.47) and after breathing was 15.78 (14.34).

CHAPTER V: DISCUSSION

General summary

This study tested the feasibility and efficacy of a fully-remote (live-streamed and recorded videos) flow-based yoga intervention for improving cognitive and psychosocial functioning, among working adults facing symptoms of stress, during a pandemic. The intervention included 5 minutes of warm-up, followed by sequences of movements derived from Hatha and Vinyasa yoga performed at moderate intensity, followed by breathing and relaxation. The purpose was to assess the impact of this remote yoga intervention on cognitive and psychosocial functioning, mainly memory, stress and positive well-being respectively, among adults with symptoms of stress. Prior research has shown efficacy of yoga in improving these constructs, most studies are conducted with low-intensity steady yoga postures. Preliminary evidence shows that different yoga styles may have different effects, and few studies have been conducted with moderate-intensity yoga. The intervention began with synchronous supervised sessions led by the yoga instructor, followed by asynchronous sessions that participants completed on their own. Thus, the intervention was titrated in terms of supervision, and was guided by the Social Cognitive Theory in terms of progressively titrated sessions. Initial sessions were aimed at facilitating self-efficacy, followed by promoting self-regulation and self-efficacy to continue with the activity, through self-guided sessions. Lastly, the study aimed to assess feasibility of learning yoga completely remotely, by interacting with the instructor through videoconferencing, and continued learning and engagement through asynchronous videos.

Intervention feasibility and fidelity

Overall, participants enjoyed participating in the study. All participants reported that they would recommend the program to their family or friends. The enjoyment rating for the yoga intervention was high. Overall, we had good attendance (71.3%) in our intervention. Attendance for supervised sessions was higher as compared to the self-guided sessions that participants had to engage in on their own. This is not entirely surprising, as performing sessions on your own would require a higher level of accountability, self-efficacy, and self-regulation. Additionally, our sample was full-time working adults between the ages of 18 and 64, and they may face unique challenges in terms of balancing work, personal life, and childcare responsibilities, and are time-pressed for engaging in physical activity (Hoare, Stavreski, Jennings, & Kingwell, 2017). Indeed, half of our participants found the study to be a burden on their life, sometimes.

In line with recommendation from prior literature, we provided our participants with videos to follow during their self-guided sessions (K. J. Sherman, 2012; Ward et al., 2014). Additionally, we attempted to promote goal-setting and self-monitoring by sending weekly emails with guidance on planning their self-guided sessions, and providing logs to monitor physical and affective responses after the sessions. The attendance rate of 63% in a self-guided setting is comparable to findings from other yoga studies, with a similar duration and frequency of yoga. For example, among cancer survivors who were provided a yoga DVD along with psychological and behavioral support, 75% of the participants used the DVD to engage in yoga an average of three times/week during the eight weeks (Winters-Stone et al., 2018). Whereas other yoga interventions with asynchronous delivery method, have had substantially higher (94%; (Komatsu et al., 2016)) and lower attendance (39%; (Kvillemo et al., 2016)) rates, it is important to note that these interventions varied from the present study in terms of total program length, frequency and duration of yoga sessions. Previous studies have also found in a difference between synchronous and asynchronous delivery modes. For example, in a study comparing synchronous vs asynchronous delivery of a mindfulness intervention, adherence rates were similar across the groups (M = 63%), but completion rate of the intervention was lower for the asynchronous group (41% vs 19%) (Allexandre et al., 2016). In all the above studies, adherence was self-reported, assessed via activity completed weekly or at the end of the study.

There were few technological issues during the supervised sessions. During the session, one staff member was always present to address any technological issues, such as participant being logged out of the session, or being unable to pin the instructor. Also, the videoconferencing application we used (Zoom) became very popular during the COVID-19 pandemic, and several participants candidly reported that they had been using Zoom for months. Probably due to these reasons, there were no major technical issues, such as participant being unable to access the session, or not having adequate help to navigate the features of the application. Our data showed that the majority of the participants liked the video instruction, found it clear and easy to follow, and would use videos to continue engaging in yoga at home. Very few yoga studies have been conducted using synchronous technology, and these include qualitative studies and quantitative studies with small sample sizes. Among 15 older adults with chronic conditions who engaged in yoga via a videoconferencing application, attendance was high (90%), and participants enjoyed the intervention, but reported having issues with technology in almost half of the classes (Donesky et al., 2017).

Overall, participants were able to maintain the prescribed intensity of the intervention. The intervention was moderate-intensity, wherein the mean heart rate was 120 beats per minute, and on average, participants reached 68.92% of heart rate max. The mean rating of perceived exertion was “moderate to hard.” This is comparable to previous studies designed to have similar intensity for flow-based yoga. For example, a 60-minute Vinyasa sequence yielded an average heart rate of 109 beats per minute among yoga practitioners. In a number of flow-based moderate intensity yoga studies, heart rate has been reported to be between 60-70% of heart rate max. Our data also met the guidelines by the CDC for determining moderate-intensity activity. The CDC defines moderate intensity as an activity falling between the target heart rate of 64% to 76% of one's heart rate maximum and/or between 4 to 6 on the revised scale rating of perceived exertion scale. (*Physical activity guidelines advisory committee report*, 2008).

Intervention effects on cognitive functioning

The results partially supported our hypothesis. There was a statistically significant improvement in working memory forward and backward in the yoga group vs the control group. Whereas the improvement in Stroop task and task-switching were not statistically significant, reductions in reaction time were in the expected direction. The yoga group experienced a lower cognitive cost as compared to the control group. In general, previous studies have shown that yoga is associated with an improvement in cognitive functioning (Gothe & McAuley, 2015; Luu & Hall, 2016). However, both meta-analyses pointed to insufficient evidence of yoga's positive cognitive effect, because of small sample sizes and poor quality of studies. With respect to RCTs, an eight-week Hatha yoga intervention among older adults resulted in better response inhibition, global cognitive functioning and processing speed, as compared to the stretching group (Gothe, Kramer, & McAuley, 2017)

The impact of yoga on cognitive functioning has been more widely studied among clinical populations and clinical or healthy older adults, and not among healthy young to middle-aged adults. In a meta-analysis of effects of aerobic, resistance, and mind-body exercises, significant effects of yoga were seen in older adults (Chen et al., 2020). Similarly, other recent systematic review and meta-analyses have shown that yoga is associated with better cognitive functioning, and especially executive functioning, among healthy older adults (Chobe, Chobe, Metri, Patra, & Nagaratna, 2020; Hoy, Östh, Pascoe, Kandola, & Hallgren, 2021). The null effect in our study may be because of the younger age of our sample. In a similar study, healthy adults who were 18 to 80 years old and engaged in six weeks of Hatha yoga showed an improvement in maintenance and manipulation working memory including digit span forward and backward performance (Brunner, Abramovitch, & Etherton, 2017). They did not assess other aspects of cognitive functioning. Our study adds to the literature by showing positive and null effects of yoga on different cognitive domains, among healthy young and middle-aged adults, who are also full-time employees. This cognitive benefit to working memory may be important for this full-time working adult population, and to our participants who are university employees and are likely involved in tasks with cognitive demands rather than physical demands..

Northey et al (2018) conducted a review of aerobic, resistance exercise, and mind-body exercises and their effect on cognitive functioning. They found that yoga was not a significant moderator of exercise effects on cognitive functioning. However, tai-chi improved working memory, but not other types of functioning. It may be that working memory is most responsive to mind-body or cognitively engaging interventions. In our study, we used digit span to assess working memory. Digit span backward is a higher-order task which involves mental manipulation of verbal stimuli, whereas digit span forward measures the storage component of working memory. There was a significant effect on the more complex manipulation component. Indeed, our intervention required participants to remember sequences of postures that changed every week and to remember various dynamic modifications and additions to each posture in the sequence, which may have impacted their working memory, especially the manipulation component, more than the other constructs.

In most yoga and cognition studies, assessments of cognitive functioning were conducted in the lab. Our study is one of the few studies to conduct cognitive assessments at home, in a person's naturalistic environment. This may have affected participants' performance, especially on reaction time tasks. A study showed that reaction times were slower on a web-based version of the Stroop task as compared to the standardized version (Backx, Skirrow, Dente, Barnett, & Cormack, 2020), and the particular software and hardware used may play affect reaction times (Calcagnotto, Huskey, & Kosicki, 2021). Another study by Kim et al (2019) showed that there was no difference in reaction time delivered via Psytoolkit at home vs an E-Prime task delivered in the laboratory, however, Kim et al used a simple choice reaction time task, not a task of higher-order executive functioning. Overall, insufficient research is available to determine whether a more naturalistic environment has an effect on reaction time in higher-order tasks.

Another potential reason for the lack of group different may be change in physical activity engagement by the control group. There were no significant differences in the Fitbit steps or in the overall leisure-time physical activity score between both groups. Additionally, the control group increased in their reported frequency of engaging in moderate-intensity activity, from baseline to eight weeks. It is possible that the control group engaged in yoga or other physical activities instead of waiting for eight weeks for the yoga intervention, considering that they had joined the intervention with the intention to be physically active.

Yoga can affect cognitive functioning through a number of mechanisms, such as regulating HPA axis activity and increasing the activity of the parasympathetic nervous system. These mechanisms have been covered in detail in chapter two. One of our aims was to test the hypothesized mediation effect of stress reduction on cognitive functioning. Results showed that the yoga group had better performance on the working memory task partially due to a reduction in stress from baseline to week four. There was partial mediation and engaging in yoga continued to have a direct effect on working memory performance. Gothe, Keswani, and McAuley (2016) examined whether cortisol is the pathway through which yoga affects cognition, among older adults. The yoga intervention included postures, breathing exercises and meditation, performed 3 times/week for 60 minutes, in comparison to a group that performed stretching exercises. The yoga group showed an attenuated effect on their cortisol response when exposed to a stressor, and this effect also corresponded with higher performance on the cognitive tasks in the yoga group.

Intervention effects on anxiety and stress

The results supported our hypothesis that the intervention would result in a decrease in anxiety and stress. Specifically, we saw a decrease in stress valence, state anxiety, and anxiety and depression symptoms from baseline to follow-up. For anxiety as measured by HADS, the yoga group started in the range of 'borderline clinical anxiety' and decreased their anxiety to the normal range after the intervention. There was also a decrease in perceived stress symptoms experienced in the past month, from baseline to week four. Previous studies have shown similar results. A study with sun salutation intervention (eight minutes daily for four weeks), resulted in anxiety reduction. In another study testing a Dru yoga intervention (which focuses on movement sequences different than the present study) researchers found that after eight weeks, yoga participants decreased stress as compared to a control group (Hartfiel et al., 2012). Among full-time working adults, doing "power yoga" twice a week for 60 minutes resulted in a decrease in stress and anxiety, and an increase in general well-being (Maddux et al., 2018). Among full-time working adults, engaging in yoga for 90 minutes/week (Brems, 2015) or one hour/week either in-person or online was associated with reduction in perceived stress after 12 weeks (Wolever et al., 2012).

The stress and anxiety reduction from yoga practice may occur from several mechanisms. One such mechanism is via greater interoceptive awareness, i.e. focus on internal states, that is facilitated by focusing on breathing patterns during movement. In our study, participants reported having an internal focus of attention throughout the intervention. Interoceptive awareness affects the limbic system and anterior insula, brain areas that appear to regulate emotional experience. Interoceptive awareness can also result in greater attention to the present moment (Farb, Segal, & Anderson, 2013). There is evidence to support that yoga can increase interoceptive awareness. Specifically, among veterans with post-traumatic stress disorder, doing yoga for 12 weeks resulted in increased interoceptive awareness (Mehling et al., 2018). Similarly, Park et al (2021) showed that eight week Kripalu yoga intervention increased interoceptive awareness which correlated with stress reduction, among adults between the ages of 23 to 67. Among other mechanism measured in that study, interoceptive awareness showed the greatest increase from baseline to post-intervention. In line with this, Gard et al (2014) proposed a theoretical framework of how yoga helps develop emotional self-regulatory pathways through top-down and bottom-up processing. Top-down processing involves attentional regulation to specific parts of the body, and breathing, while doing yoga. This can lead to a reduction in ruminative thinking, sustained attention on relevant task, disregard irrelevant information, reframe bodily sensations ("feel the stretch" instead of "pain"), and increase meta-awareness or mindfulness, all of which contribute to regulating emotional responses to stress. Emotional regulation through bottom-up process involves interoception, being aware of one's bodily sensations, and engaging in diaphragmatic breathing which influences activation of the parasympathetic nervous system. As one acquires more yoga experience, bottom-up processes may strengthen. Gard et al propose that yoga leads to an integration of these top-down and bottom-up process, which in turn ultimately contributes to better emotional self-regulation and stress reduction in daily life.

Another potential mechanism is an increase in mindfulness, which refers to intentionally paying attention to one's moment by moment experience without judgment (Kabat-Zinn, 2003). Yoga may facilitate mindfulness by bringing attention to the breath and one's internal states. As attention wanders, one takes note of it, allows thoughts to pass by without judgment, and brings the focus back to breathing. A number of studies have shown that yoga is associated with an increase in mindfulness. Park et al (2021) assessed the underlying mechanism of stress reduction, among young to middle-aged adults engaged in a 12-week Kripalu yoga intervention. Psychosocial stress was assessed at baseline, mid-intervention, and post-intervention. Results showed that mindfulness increase from baseline to post-intervention, and was significantly correlated with stress reduction. In a meta-analysis of studies on mindfulness-based stress reduction, which intends to reduce stress by increasing mindfulness and includes an aspect of Hatha yoga, a majority of the studies significantly reduced stress (Chiesa & Serretti, 2009). Another potential mechanism underlying yoga's benefits could be adaptations to the musculoskeletal system, which can in turn affect body awareness and embodied emotion, and decrease psychological distress (Francis & Beemer, 2019). For example, strengthening one's muscles and increasing flexibility can lead to better posture, more energy and endurance, and being aware of one's body can help detect emotional reactions to stressors (e.g., increase heart rate).

Other potential mechanisms include an increase in self-compassion and positive affect. We found that self-compassion, positive affect, and negative affect, partially mediated the effect of yoga on stress. That is, a reduction in stress was a result of engaging in yoga as well as an increase in self-compassion and positive affect, and a reduction in negative affect. There is not much prior research on self-compassion and affect as mediators for stress change. Park et al (2021) found that an increase in self-compassion was correlated with a reduction in stress after a 12-week yoga RCT. Among young adults who participated in a four-month residential yoga program, an increase in self-compassion predicted a reduction in stress at the end of the program (Gard et al., 2012; Luo et al., 2019). Similar results were seen among students who engaged in a one-year yoga program (Gorvine, Zaller, Hudson, Demers, & Kennedy, 2019). West et al (2004) found that a change in affect was not related to a change in cortisol, after an acute 90-minute bout of yoga. Among cancer survivors participating in a seven-week yoga program, affect was predictive of psychological well-being (Mackenzie, Carlson, Ekkekakis, Paskevich, & Culos-Reed, 2013).

There are biological and physiological mechanisms that facilitate stress reduction. The mechanisms underlying changes in cognitive functioning mentioned previously, appear to play a role in stress reduction. Several studies have shown a reduction in cortisol after engaging in yoga (Eda et al., 2018; Pascoe & Bauer, 2015; West et al., 2004). Several yoga studies have also shown changes in heart rate variability after engaging yoga (R. P. Brown & Gerbarg, 2009; Satyapriya et al., 2009; Sawane & Gupta, 2015), although most research is focused on breathing or meditation techniques only. This increase in parasympathetic activity can prolong reactivity to stress, meaning that one would require a higher level of stress to elicit the same physiological response, and also influences perceptions of stress. For example, interpreting a steady heart rate as feeling less stressed in situations that would previously be viewed as stressful. Other biological mechanisms including inflammatory factors, such as interleukin-6 (Yadav, Magan, Mehta, Sharma, & Mahapatra, 2012), and changes in gene expression (Black et al., 2013) have been found after yoga interventions, but far less is understood about them.

Intervention effects on social cognitive theory constructs

The yoga intervention resulted in an increase in self-efficacy for engaging in yoga postures, breathing exercises, and meditative exercises, in the yoga group whereas self-efficacy declined in the control group. The data supported our hypothesis in the expected direction. Additionally, there was no significant effect of prior yoga experience on yoga self-efficacy. Typically, self-efficacy can be increased from four sources- mastery, vicarious experience, verbal persuasion, and physiological and affective states - of which mastery may be one of the most influential sources (Bandura, 2004). Mastery experience refers to learning a skill by actually performing the task. Being successful in performing a task can increase one's belief to engage in the task successfully. Participants engaged in individual sessions with personalized feedback and supervised classes led by an instructor, before performing the activity by themselves. By doing so, participants may have increased in their mastery experience and may have felt more confident about performing the movements. Self-efficacy may have also increased at the beginning, due to verbal persuasion, which refers to appraisal of one's ability provided by another person. Verbal persuasion may be more effective when the feedback is based on one's exercise performance, realistic, provided in a timely manner, and from a credible and trustworthy source (Ashford et al., 2010; Booth, Owen, Bauman, Clavisi, & Leslie, 2000; L. L. Lee, Arthur, & Avis, 2008).

In the individual sessions, feedback was provided by our trained and certified yoga instructor during and immediately after performing the movements, which may have increased self-efficacy for engaging in yoga. Additionally, participants also had to note down their heart rate, exertion, and affect after every session. This may have prompted them to keep track of their physiological adaption, i.e., changes in their physiological and affective responses to the activity, over the course of eight weeks. There was no change in self-efficacy for engaging in walking, or self-efficacy for overcoming barriers to engage in physical activity. This may be because self-efficacy is task specific, and higher self-efficacy on one task does not necessitate change on another task (S. Smith, Kass, Rotunda, & Schneider, 2006). Our intervention did not include walking or advocate involvement in other aerobic activities. Thus, participants did not increase in their self-efficacy. Self-efficacy to overcome barriers may not have increased because the intervention did not involve behavior change techniques to address barriers to physical activity. Exercise self-efficacy may play a role in exercise adoption, and barriers self-efficacy is related to exercise maintenance (Higgins, Middleton, Winner, Janelle, & Middleton, 2014). Our study was only eight weeks long and targeted adults who were low active.

There was an overall increase in self-regulation, and in goal-setting, time management, and relapse prevention, in the yoga group. As expected, there was no change in self-monitoring, social support, and reinforcement. There was no significant effect of prior yoga experience on self-regulation. Self-regulation is the process of regulating one's own thoughts, behaviors, and feelings in order to complete a desired behavior (Hofmann, Schmeichel, & Baddeley, 2012). Our study was titrated in terms of supervision. For the last three weeks of the intervention, participants were on their own to do all sessions. This may have resulted in an overall increase in self-regulation, as participants had to manage their time, responsibilities, and set and achieve goals for a new behavior. To help participants in planning their self-guided sessions, we sent them a weekly email with guidelines on setting goals and making time for the sessions. This mayhave contributed to an increase in their goal-setting and time-management skills, and relapse prevention may have increased by providing autonomy to participants to engage in physical activity in their daily lives. It is not surprising that self-monitoring, social support and reinforcement showed no change at the end of eight weeks, given the design of the study. Although the intervention started with individual supervised and group sessions that may facilitate reinforcement and social support, the rest of the intervention consisted of self-guided sessions following a video. We did not attempt to provide continued reinforcement or social support through any aspects of the study. However, there was no significant decline in social support, meaning that the online sessions and titrated delivery format did not make people feel more isolated. We asked participants to track their activity through Fitbit and logs, whereas this scale measured self-monitoring by keeping mental track of activities. There were no changes in physical, self-evaluative, or social outcome expectations. Outcome expectations refers to anticipated outcomes from engaging in a particular behavior (Bandura, 1997). We assessed physical, social, and self-evaluative outcome expectations, and did not observe group differences in any of those constructs. These may not have increased because our intervention did not specifically aim to change outcome expectations. Another reason could be that participants had realistic outcome expectations to begin with, and thus engaging in the intervention did not modify outcome expectations. We did not attempt to modify perceptions about whether yoga would increase physical health, elevate social standing or self-worth.

Increases in self-efficacy and self-regulation, which are related to each other, are crucial for continued engagement in physical activity. Several studies have shown that these constructs predict physical activity engagement in an intervention (Knittle et al., 2018) and sustained engagement in physical activity (Buckley, Cohen, Kramer, McAuley, & Mullen, 2014; M. Umstattd, Wilcox, Saunders, Watkins, & Dowda, 2008). For example, having higher self-regulation and executive functioning at baseline was associated with an increase in exercise self-efficacy at week three, which predicted exercise adherence for the year-long exercise trial (McAuley et al., 2011). The implication for the present study is that increasing participants' self-efficacy and self-regulation increases the chances that they will continue engaging in physical activity even after the intervention is over. Targeting these constructs directly may have increased adherence and engagement in our sample, as they were low-active before starting the intervention.

Intervention effects on positive psychological well-being

The intervention resulted in an increase in mindfulness and optimism at week four, and in overall self-compassion, and positive and negative affect, at week eight. Constructs measuring positive psychological well-being were included because a reduction in negative well-being does not equate an increase in positive well-being (Boehm & Kubzansky, 2012). While most research on mind-body activities has focused on reductions in anxiety, depression, and stress, there is growing evidence that these interventions can affect positive aspects of mental health as well (Domingues, 2018; Riley & Park, 2015), although until 2018, only 5% of the studies have assessed positive psychological well-being (Domingues, 2018).

Our results are supported by previous studies. Gard et al (2012) found that mindfulness increased after a four-month yoga intervention among health young adults, and it mediated the effect on quality of life. In our study, mindfulness increased at week four but the increase was not sustained at week eight. This may be because all of the sessions, except one, after week four were self-guided sessions. During supervised sessions, the instructor prompted mindful attentionby verbal suggestions and cues (e.g., focus your attention on your breath), and presence of other participants may have created more accountability and group coherence. These suggestions and social factors are integral to developing mindfulness (Canby et al., 2021;

Farb, 2012). Mindfulness is also a trait disposition that takes years of practice to develop, and a duration of eight weeks may be insufficient to increase it substantially (K. Brown & Ryan, 2003; Domingues, 2018). Thus, a lack of instructor and group presence coupled with a relatively shortintervention may have been the reason for the drop in mindfulness after week four. Although completely speculative, this may have been the case with optimism as well, but there is little research to corroborate this idea. Among specific populations such as incarcerated individuals and pregnant women, engaging in a yoga program was associated with higher optimism at the end of the intervention (Reis & Alligood, 2014; White, Schneider, Ma, & White, 2014).

It is not surprising that our eight-week intervention led to an overall increase in self-compassion, as self-compassion shows an increase in yoga interventions that are shorter in length (Domingues, 2018). Self-compassion has also been found to be a mediator of yoga and psychological well-being (Gard et al., 2012). Impact on PPWB may also depend on styles of yoga. Particular styles of yoga may promote self-compassion, such as Kripalu yoga which literally means compassion, and the focus is on introspection and compassion towards oneself (Gard et al., 2012). In our study, self-compassion may have increased with a corresponding increase in interoception and an awareness towards one’s internal states (Cox, Ullrich-French, Tylka, & McMahon, 2019), and mindfulness. Indeed, self-compassion and mindfulness are connected with each other as one of the main tenets of self-compassion is mindfulness (Neff, 2003) and self-compassion is a mediator of mindfulness (Birnie, Speca, & Carlson, 2010). The intervention also resulted in an increase in positive affect, and a decrease in negative affect. Previous studies have shown similar results. In an eight-week flow-based Vinyasa yoga intervention for college students, affect was measured before and after each session. Positive affect increased and negative affect decreased in more than 85% of the sessions, and overall, showed a significant change from baseline to eight weeks (Gaskins et al., 2014). Among participants with type 2 diabetes, participating in an eight week yoga intervention for three-six days per week resulted in a decrease in negative affect post-intervention (McDermott et al., 2014). In another eight week intervention, engaging in flow-based yoga was associated with an increase in positive affect and decrease in negative affect (Hartfiel et al., 2012). In a weeklong yoga program for participants across the lifespan (13-78 years), a 17% increase in positive affect and 47% reduction in negative affect was observed (Narasimhan, Nagarathna, & Nagendra, 2011).

Increases in positive well-being are associated with better health and an increase in physical activity. Boehm (2012) showed that an increase in emotional well-being, sense of mastery, life satisfaction, optimism, and positive affect is associated with a lower risk of cardiovascular disease or cardiovascular disease related mortality, in prospective studies across large sample sizes (e.g. 70,000) accounting for confounding factors. Positive affect has been associated with lesser symptoms of depression (Schütz et al., 2013), and greater quality of life and perceived health among cancer patients (Hirsch, Floyd, & Duberstein, 2012). Among those with highly stressful jobs, a higher level of negative affect has been associated with more stress (Hamama et al., 2013). Optimism is associated with a higher level of physical activity (Boehm & Kubzansky, 2012).

Strengths and limitations

This study has a number of strengths. This study was pre-registered through Clinicaltrials.gov, adhering to guidelines of open science. It is a randomized controlled trial (RCT), which is one of the most rigorous scientific methods. Apart from being a RCT, the study design was rigorous in terms having blinded assessors who were not aware of participants' group assignment, and a blinded interventionist who did not conduct any assessments for the participants. The interventionist was a certified yoga instructor, who trained in the specific yoga protocol used in this study, for over six months. The remote delivery of the intervention and the assessments was a strength of this study. Especially during the times of a pandemic, providing an intervention remotely to participants meant no exposure to other people and ensuring the safety of one's health. Additionally, they did not have to face barriers such as access to transportation, time spent traveling, and dealing with changes in lockdown and other pandemic-related regulations. There were minimal technical difficulties and the intervention was delivered over Zoom, a web-based and mobile-based application, which most participants had already been using prior to the intervention. The features provided by Zoom ensured that participants were only watching the yoga instructor during the class, and not watching other participants. This allowed participants to watch the instructor on a full screen and while maintaining some level of privacy. The flexibility of choosing which days participants would engage in the group sessions provided more flexibility to participants. The adherence level during self-guided sessions was low, and this can be improved by providing more support using behavioral change techniques. Another major strength was the titrated nature of the intervention, moving from individualized sessions to completely self-guided sessions, and using a theory-guided method. This increased the external validity of the study, as it was not a tightly controlled experiment in the lab and allowed participants to engage in physical activity in their natural setting. The purpose of this was to provide autonomy to participants to incorporate physical activity into their schedule on their own terms, to promote self-regulation of physical activity by engaging in planning their sessions and self-monitoring their engagement, and to allow them to incorporate any lifestyle changes the pandemic may have caused (e.g., having kids at home the full day). At the same time, participants were given guidance on performing the movements by conducting individualized sessions and group classes. Providing flexibility to fit activity into their schedule may be especially important for full-time working adults given their perceived lack of time to engage in physical activity. Other strengths of this study include the use of a Fitbit, as an objective method to track attendance, heart rate after yoga sessions, and overall physical activity.

This study design and findings should be viewed with caution due to several limitations. One of the major limitations is the lack of an active control group. The effects of the intervention could not be compared with other physical activities to examine the efficacy of moderate-intensity yoga in comparison to other activities. This also meant that the control group participants did not immediately receive an intervention as a part of the study. However, we did provide them the same yoga intervention after their study participation was over. The study sample was homogenous in terms of demographics, and employment type. Participants were mostly female, white, and non-Hispanic. All participants except one, were state government employees and most of them were UIUC employees. It is not surprising that most of our sample consisted of UIUC employees, given that recruitment was conducted through e-week newsletter distributed only to UIUC staff and faculty. Because of the pandemic, an active effort to a sample from the community, through recruitment flyers in cafes and grocery stores, was not made. Another limitation is the possibility of demand characteristics and social desirability bias. It was not possible to mask study assignment for the participants, so they were aware of whether they were in the experimental group or the control group. The study was advertised as assessing the effects of yoga on health outcomes. Even though participants were not informed about the specific aims and outcomes of the study, they may have been able to guess it based on the assessments. Participants may have answered the surveys in a way that conforms to what they believe to be the hypothesis. Another limitation is the restricted availability of the group sessionsas they were offered only in the evening, most likely after work. Participants may have been more stressed after work. Another limitation is that baseline and post-testing appointments were conducted throughout the day, and there are phasic shifts in stress levels throughout the day which can impact cognitive test performance (Dickmeis, 2009; Plieger et al., 2017). In the future,cognitive testing appointments can be conducted during the same time of the day for all participants, to minimize the effect of stress on their performance.

Implications and directions for future research

Our study was conducted during the COVID-19 pandemic, among people with stress and anxiety. Mental health conditions including depression and anxiety were already one of the leading causes of disability and health burden across the globe, pre-pandemic. These disorders have been exacerbated by the pandemic, leading to an approximate increase of 25% in their prevalence worldwide (Taquet, Holmes, & Harrison, 2021). There was a higher prevalence of depressive and anxiety disorders among young adults and females (Santomauro et al., 2021). Importantly, reduction in human mobility was an independent predictor of an increase in these mental conditions. Given these data, our results hold substantial value. It was seen that engaging in yoga reduced stress, anxiety, depressive symptoms, increased positive psychological well-being, and improved Covid-related emotional well-being among those facing symptoms of stress. Furthermore, our intervention was completely remote, home-based, involving individual physical activity, keeping in mind safety and mobility restrictions due to the pandemic. Thus, this study provides support for conducting remote, home-based physical activity interventions to alleviate the deterioration of psychological well-being due to the pandemic.

The overall attendance in our study was 75%, and attendance for self-guided sessions was much less than live sessions with supervision (63.50 vs 97.15%). While self-guided sessions may provide more opportunities for engaging in physical activity according to one's schedule and encourage self-regulation, the experience is very different from live instruction in the context of group classes following a structured schedule. We attempted to encourage engagement in self-guided sessions by sending weekly emails with strategies for planning one's sessions. Our study also encouraged self-monitoring of physiological and affective responses to the sessions, by answering post-session logs. However, there are a wide variety of behavioral change techniques (BCTs) to increase engagement in physical activity (Michie et al., 2011). These BCTs can additionally be combined with features of technologies being used in the study. Future studies can investigate which combination of behavioral change strategies to use, to maximize engagement. Individualized or targeted interventions can be developed, using BCTs according to participant characteristics such as demographics and baseline fitness levels and delivery method of the intervention (Carraça et al., 2021).

More than half of the participants in our study were did not have good dietary habits, reportedly consuming high fat foods and foods high in sugar, and were overweight. Future studies can consider targeting dietary habits along with physical activity. For example, Vandelanotte et al (2008) conducted an intervention to increase physical activity and decrease fat intake. Thirty-three percent of the participants were successful in changing both the targeted behaviors, and those who were overweight were more likely to change their behavior. Apart from participant characteristics, targeted outcomes may also play a role in deciding whether to implement a single or a multiple health behavior change intervention (Sweet & Fortier, 2010).

Multiple change interventions were better for weight loss, whereas single change interventions were better for improving the targeted behavior. Future studies can implement single or multiple behavior change interventions depending on their outcomes and participant characteristics, such as body weight, age, and prior experience with yoga.

Another factor to consider in a home-based, tech-delivered intervention, is access to technology. Our participants were employed, with a mean income of in the range of $75,000-$99,999, and had access to a laptop or a tablet with internet connectivity. However, computer ownership and internet usage may vary across demographic and geographic factors. For example, in 2018, 86% of urban house-holds vs 81% of rural households had internet access. People who had a lower socioeconomic status, disability, or limited English speaking ability were less likely to have internet access. It was more likely for people from a lower socioeconomic status, with a Black or Hispanic young adult householder to have access to smartphones as compared to laptops or computers. Future studies should use appropriate technology depending on their targeted sample. Studies can also consider using smartphones and mobile applications to deliver the intervention, given that more people have smartphones than computers.

The characteristics of our instructor may have affected engagement of the participants. Our instructor was young, Caucasian, female and in college whereas our participants were full-time working adults with a mean age of 41 years, 17.4% male, and from diverse race and ethnicities. It may be that only young, female participants in our study were able to relate to the instructor, and form a stronger bond which may have influenced their engagement. Participants' self-efficacy for doing self-guided sessions may have been influenced by the instructor's characteristics, as one of the sources of self-efficacy is observing someone with similar characteristics as yourself, succeed at the task (Bandura, 1998). Although participants' self-efficacy for yoga increased at the end of the study, other types of self-efficacy did not increase, and it may be important to study whether instructor characteristics may be at play. Similarly, it is important to examine how participant characteristics, such as their culture, language, and familiarity with yoga, may have impacted their engagement. Although Yoga is gaining popularity in the US, it originated in and has been popular for centuries in Asian countries. It is likely that it may be easier for Asian participants to relate to yoga, to fully give oneself to it by having heightened interoceptive awareness (Ma-Kellams, 2014), and there may be cultural differences in factors that predict engagement (Tolbaños-Roche & Menon, 2021). Future studies should consider having an instructor with characteristics similar to the participants, or examine the effect of instructor characteristics on engagement. For example, in a focus group discussion of older adults participating in a Tai-Chi program, participants reported that it was important to have an instructor who was older and thus understood the physical barriers of engaging in exercise (Manson, Tamim, & Baker, 2015). Gould and Weiss (1981), found that students performed better on a leg extension endurance task after watching a nonathletic person demonstrate the task, as compared to an athletic model who also provided positive self-talk. Similarly, among college students who had low athletic experience, students who modeled a non-athletic demonstrator performed better on the endurance task, and had higher self-efficacy, than those who modeled an athletic demonstrator (George, Feltz, & Chase, 1992). Additionally, perceived similarity with other participants in the intervention may influence adherence. Beauchamp et al (2011) found that in a six to eight week group physical activity intervention, attendance was predicted by participants' perception of being similar in age to other participants. Likewise, age similarity predicted adherence to exercise programs over a number of months

(Dunlop & Beauchamp, 2012). Thus, having an instructor and other participants who are similar in characteristics such as age and experience may be important.

It is important to note that this study was conducted during a pandemic. All of our participants were facing an unprecedented situation. They may have responded differently to our outcome variables, and to the remote intervention, because of the pandemic. It is likely that our participants worked from home. A survey of 456 government-employed teleworkers revealed that teleworking appears to contribute to the perception of feeling “time-pressed” by expanding and intruding on free time (Thulin, Vilhelmson, & Johansson, 2019). Feeling time-pressed, having to adjust to a new routine of working from home, and dealing with the pandemic may have affected responses and attendance.

As previously mentioned, a variety of psychological and biological mechanism have been proposed for psychosocial benefits of yoga, but they have not been investigated systematically. There may be an interaction between one or more of these mechanisms. For example, an increase in interoceptive awareness and mindfulness are some potential mechanisms, but engaging in mindfulness itself requires interoceptive awareness. Some mechanism may be more important than others depending on the style of yoga. For example, self-compassion may be a key mechanism for Kripalu yoga, more so than Hatha yoga as the cornerstone of Kripalu yoga is being kind to oneself. Future studies can investigate the underlying mechanisms, and the unique features of mind-body practices, that affect psychosocial functioning.

Conclusion

This study showed that it is feasible to deliver a moderate-intensity flow-based yoga intervention using synchronous and asynchronous technology, at home, for working adults with symptoms of stress, during a pandemic. The intervention resulted in an increase in working memory and did not significantly affect other aspects of cognitive functioning. Overall, the intervention decreased anxiety and stress, and improved self-efficacy, self-regulation, and positive well-being. Findings from study may be useful for individuals looking to alleviate stress and anxiety, and improve well-being, without having to compromise on safety and mobility restrictions during the pandemic.

CHAPTER VI: FIGURES

Figure 1

Integrated model of Technology Acceptance Model and Social Cognitive Theory

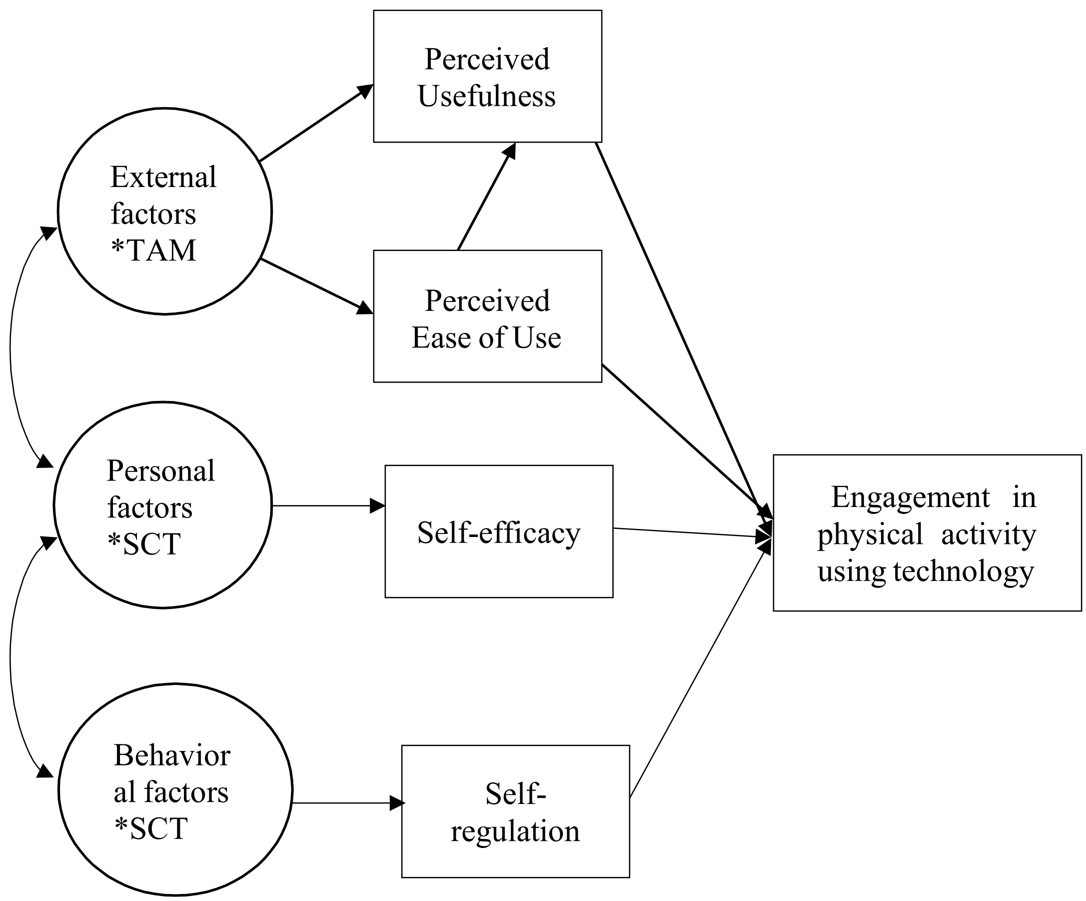


Figure 2

Theoretical mechanisms regarding retention in the intervention

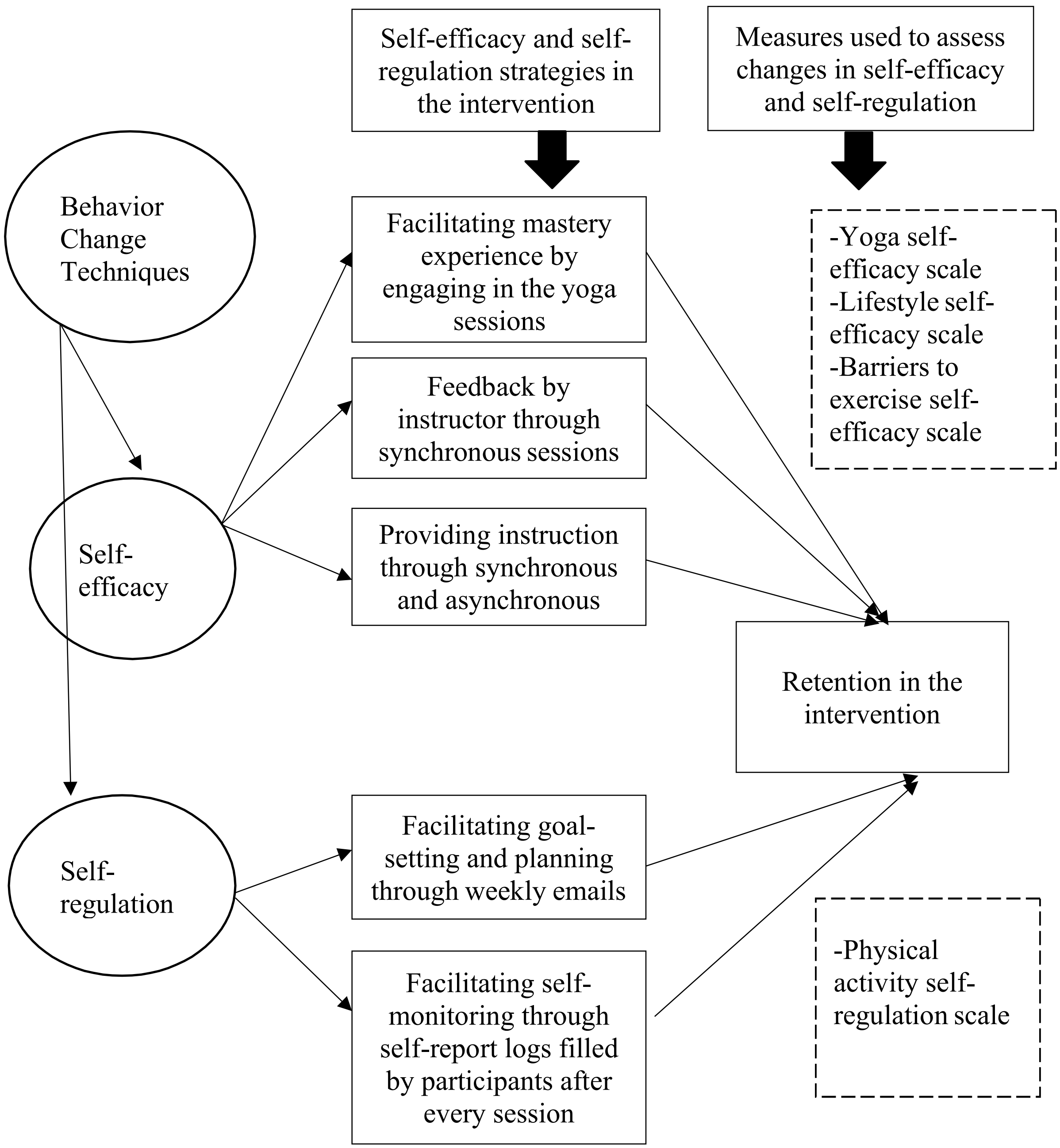


Figure 3

Theoretical mechanisms underlying the effect of the intervention on outcome measures

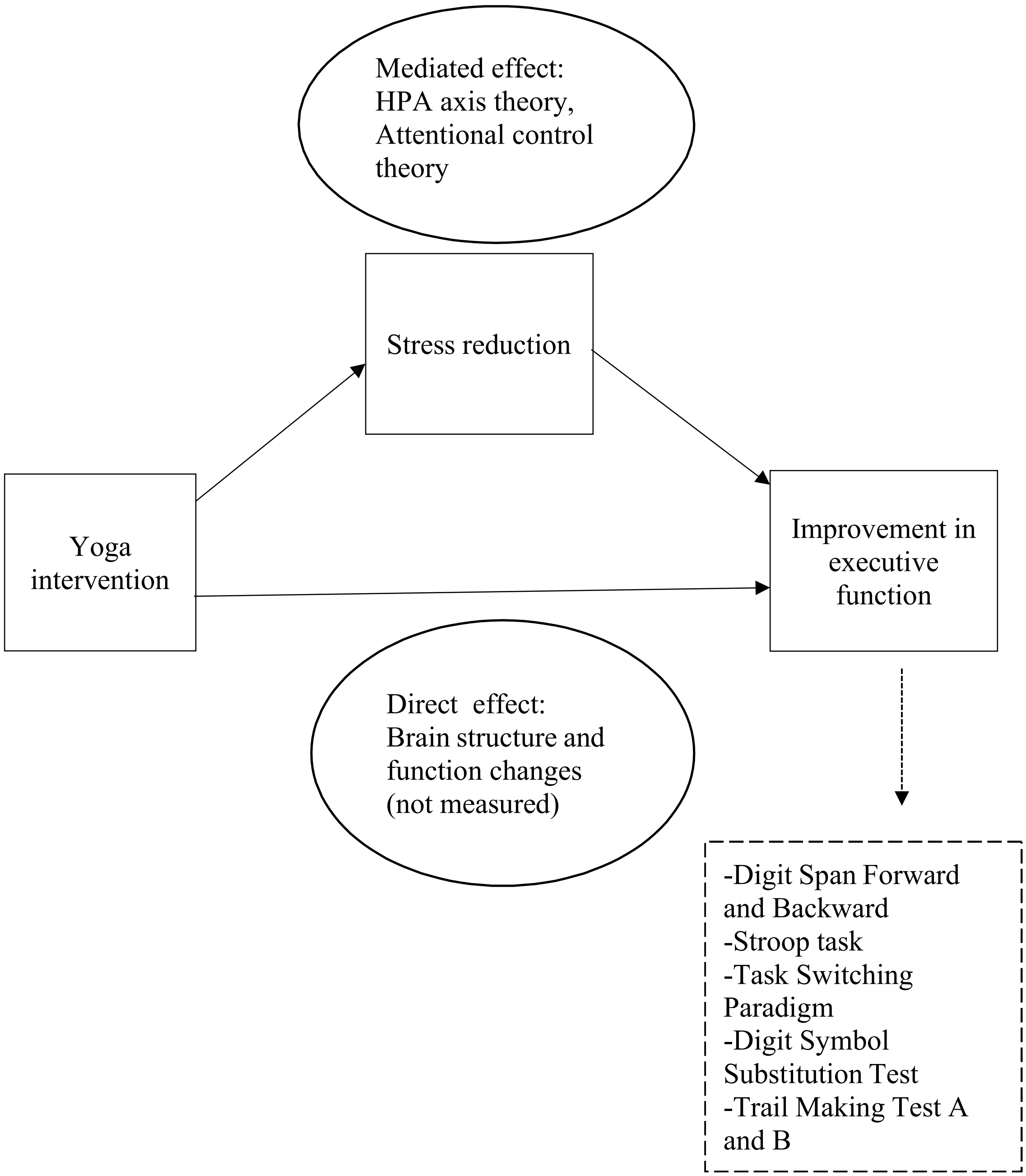


Figure 4

Study timeline

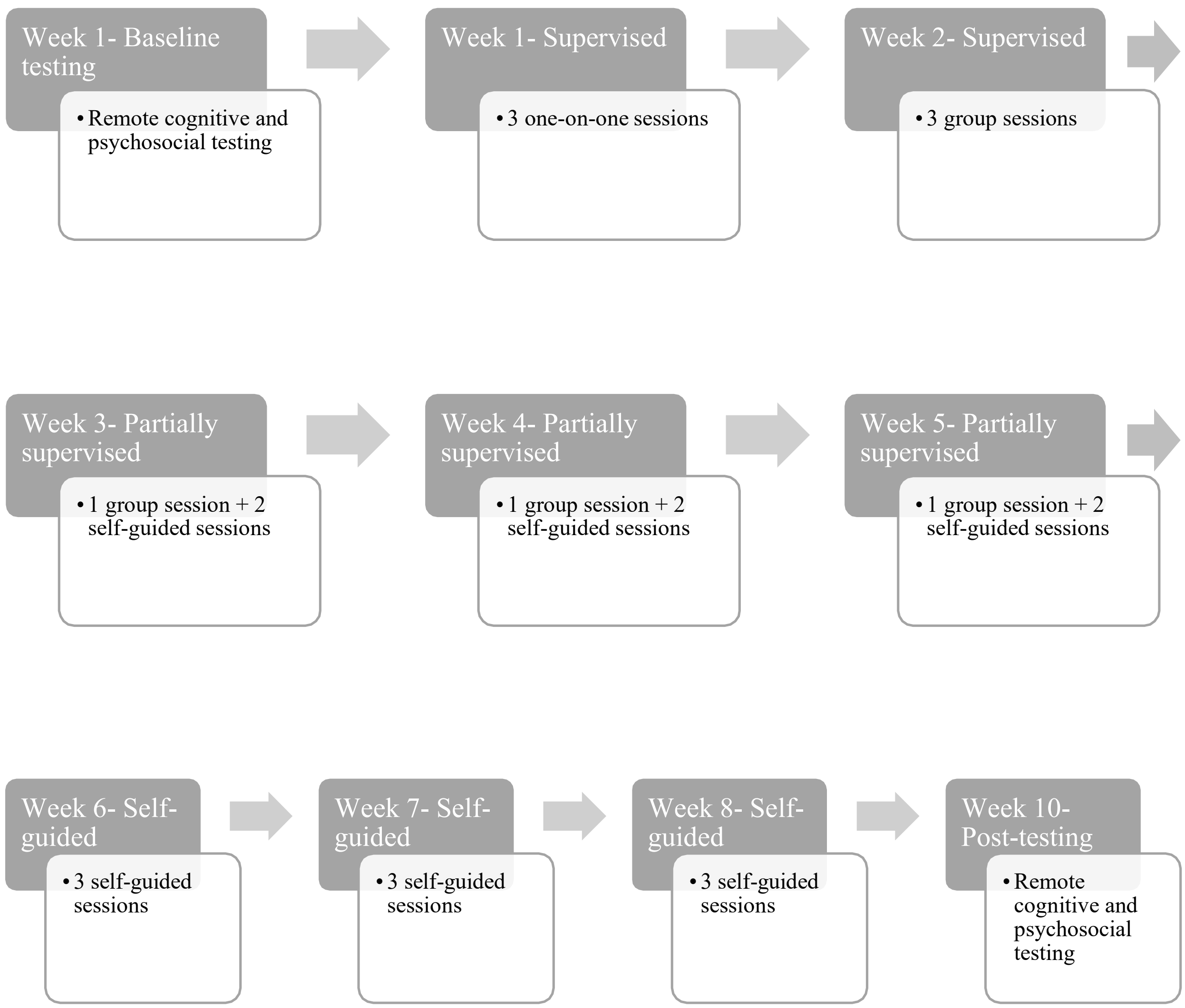


Figure 5

Consort

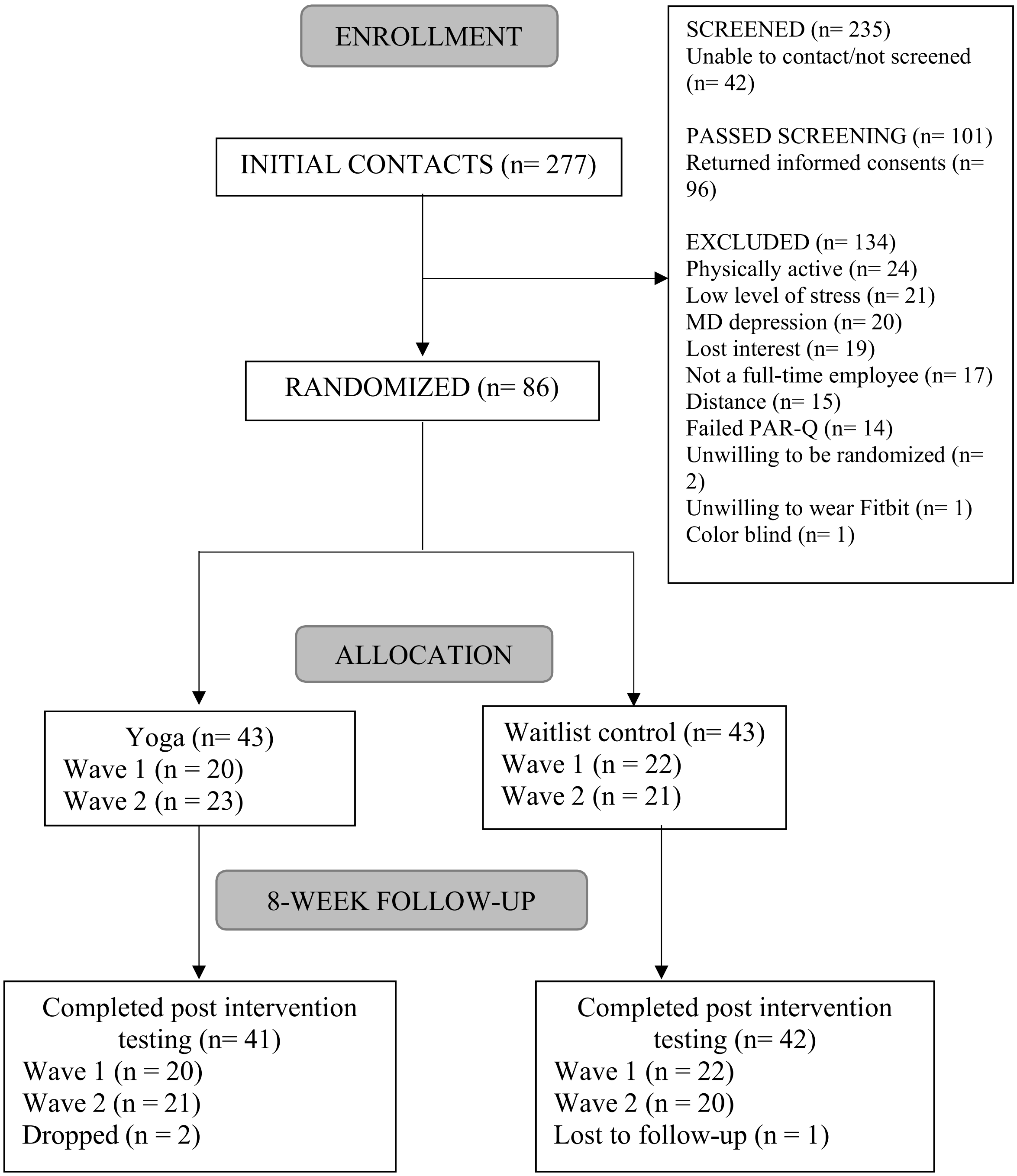


Figure 6

Means for digit span forward and backward

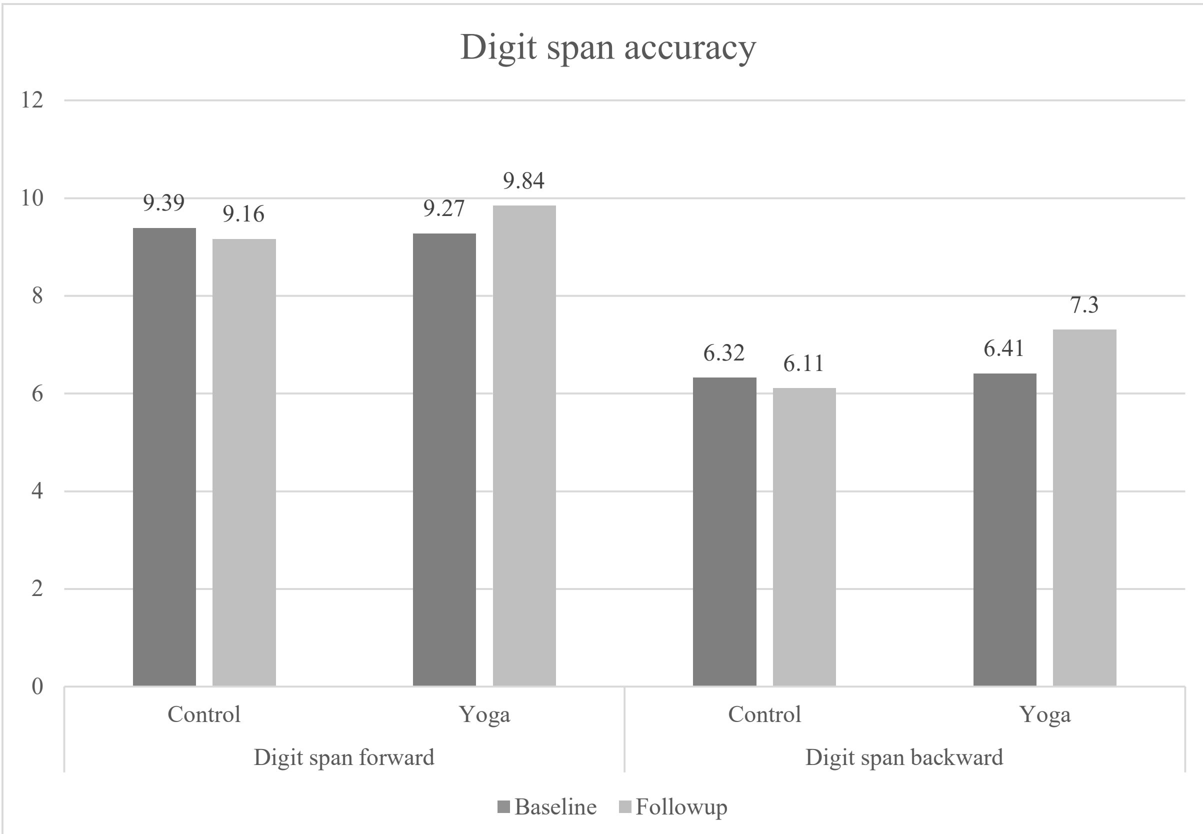
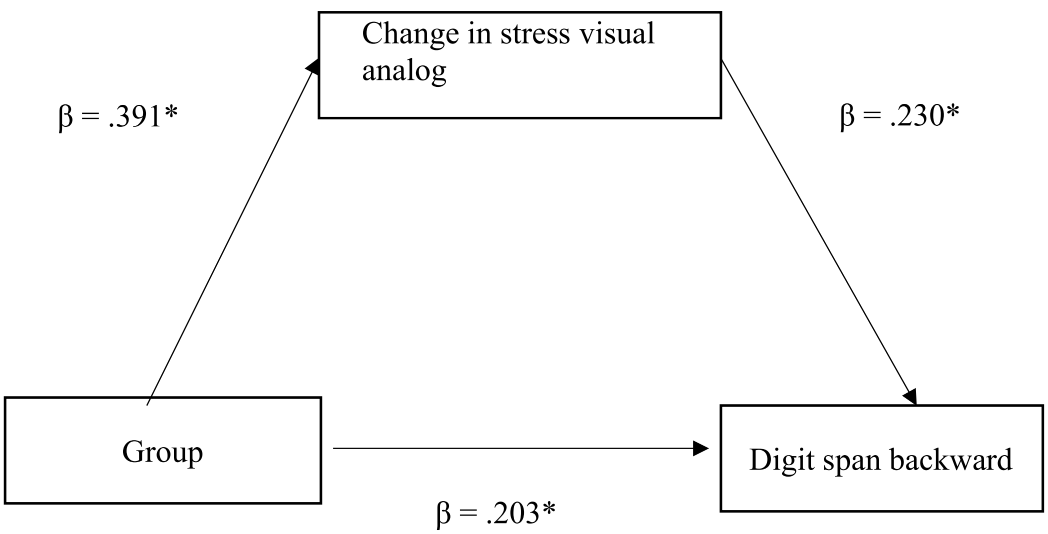


Figure 7

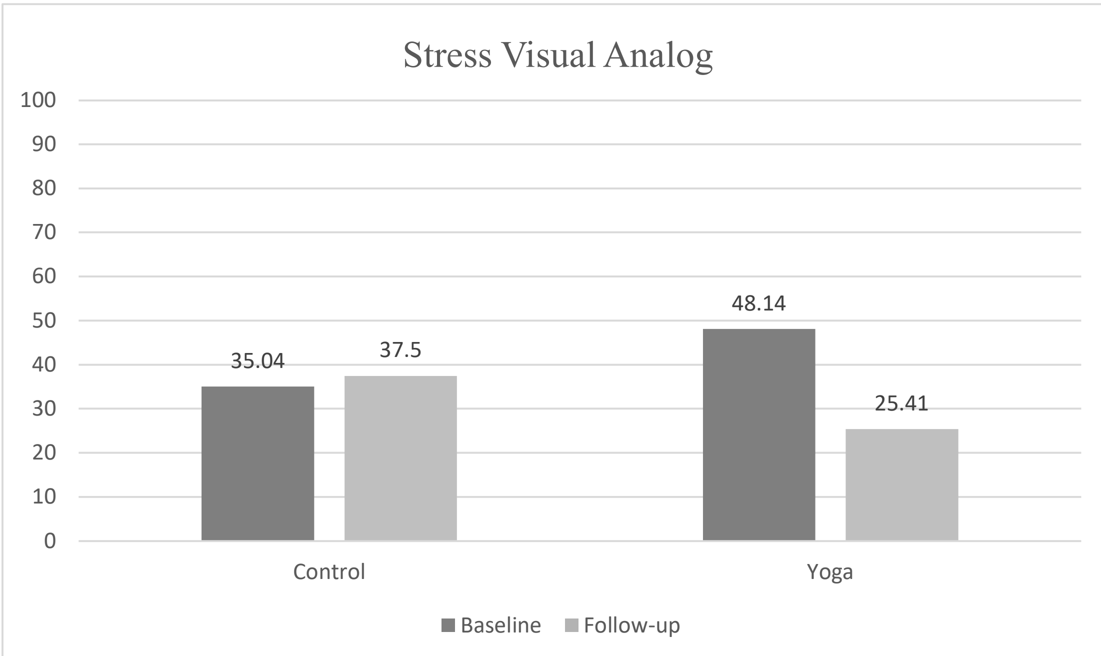
Mediation analysis



Note: Standardized regression coefficients are shown for the relationship between group and digit span backward as mediated by change in stress scores. *$p < 0.05$.

Figure 8

Means for stress visual analog scale



CHAPTER VII: TABLES

Table 1

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age between 18 and 64 years.	Age below 18 years or above 64 years
Full-time working adults, defined as working >35 hrs/week in any industry, and not currently enrolled as a full-time student.	Students or part-time working adults
Presence of at least three symptoms of stressor anxiety as measured by the symptom checklist from the *Diagnostic and Statistical Manual VI.*	Presence of two or less symptoms of stress or anxiety as measured by the symptom checklist from the *Diagnostic and Statistical Manual VI.*
Low active, i.e. participating in physical activity and/or mind-body activities such as yoga and tai-chi less than 3 times/week for 30minutes, in the last three months.	Engaging in high levels of physical activity (≥30 minutes, two or more times/week, for the last three months) and/or a regular practitioner of Yoga or mind-body activities such as tai-chi and mindfulness meditation (≥ 30 minutes, two or more times/week, for the last three months) and/or a certified yoga teacher.
Ability to exercise at a moderate intensity, and perform movements including sitting,	Mobility impairment restricting ability to engage in moderate intensity activity.

Table 1 (cont.)

standing, kicking, pulling, pushing, bending one's elbows, bending the body forward, bending one's knees, lying down and getting up without difficulty.	
No engagement in mindful activities, such as meditation, or brain training games, for greater than 3 times/week for 30 minutes, in the last three months.	Engagement in mindful activities, such as meditation, or brain training games, for greater than 3 times/week for 30 minutes, in the last three months
Currently not involved in any other research study related to physical activity, mind-body activities, or brain training games.	Currently involved in research study relatedto physical activity, mind-body activities, or brain training games
Access to a yoga mat, and a smartphone witha data plan or access to WiFi, on which an application could be downloaded.	No access to yoga mat or a smartphone with data or WiFi, as well as refusal to download a health application on their smartphone.
Access to a laptop or desktop with an attached keyboard	Refusal or unwillingness to be randomized into either of the conditions.
Willingness to be randomized to one of two conditions Fluent in English language	Having any of the following medical conditions, including risk of seizure, psychiatric and/or neurological disorders, ordiagnosed hypertension or blood pressure of 200/105 or more.
-	Score of >1 on the Physical Activity Readiness Questionnaire.

Table 1 (cont.)

-	Unavailable for >one week in the 10-week study Prior yoga experience in the last 10 years, i.e. those who have engaged in consecutive 50 weeks of yoga sessions each lasting 60 minutes, without missing 12 weeks or more

Table 2

Table of measures

Construct	Measure	Assessment Time-Point
Health History	Health History Questionnaire	Screening and baseline
Demographics	Demographics Questionnaire	Screening and baseline
Cardiorespiratory fitness	Cardiorespiratory Fitness Questionnaire	Baseline, 8-week Follow-up
Primary Outcomes		
Working memory	Digit span forward and backward	Baseline, 8-week Follow-up
Response inhibition	Stroop task	Baseline, 8-week Follow-up
Cognitive flexibility	Task Switching paradigm	Baseline, 8-week Follow-up
Processing speed	Digit Symbol Substitution Test	Baseline, 8-week Follow-up
Secondary Outcomes		
General and Job-related Stress	Brief Job Stress Questionnaire (BJSQ) (Kawada & Otsuka, 2011)	Baseline, 4 week, 8-week Follow-up
	Perceived Stress Scale (PSS) (S. Cohen et al., 1983)	Baseline, 4 week, 8-week Follow-up
	Stress Visual Analogue Scale	Baseline, 8-week Follow-up
Anxiety and Depression	Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983)	Baseline, 8-week Follow-up
	State Trait Anxiety Inventory (Spielberger, 2010)	Baseline, week 4, 8-week Follow-up
Self-efficacy	Yoga Self-efficacy Scale (Birdee et al., 2016)	Baseline, week 4, 8-week Follow-up
	Lifestyle Efficacy Scale (LSE) (McAuley et al., 2009)	Baseline, week 4, 8-week Follow-up
	Barriers to Exercise Self-efficacy Scale (BARSE) (McAuley, 1992)	Baseline, week 4, 8-week Follow-up

Table 2 (cont.)

Mindfulness	Mindfulness and Attention Awareness Scale (K. Brown & Ryan, 2003)	Baseline, week 4, 8-week Follow-up
Self-compassion	Self-Compassion Scale (Neff, 2003)	Baseline, week 4, 8-week Follow-up
Positive and Negative Affect	Positive and Negative Affect Schedule (Watson et al., 1988)	Baseline, week 4, 8-week Follow-up
Optimism	Questionnaire for the Assessment of Personal Optimism and Social Optimism-Extended (Gavrilov-Jerković et al., 2014)	Baseline, week 4, 8-week Follow-up
Bodily changes	Experienced Bodily Changes Scale (O'Connor et al., 2004)	Baseline, 8-week Follow-up
Physical activity	Godin Leisure-Time Exercise Questionnaire (GLTEQ) (G Godin & Shephard, 1985)	Baseline, 8-week Follow-up
Outcome Expectations	Multidimensional Outcome Expectations for Exercise Scale (MOEES) (Wójcicki, White, & McAuley, 2009)	Baseline, 8-week Follow-up
Self-regulation	Physical Activity Self-regulation Scale (PASR) (Hallam & Petosa, 1998)	Baseline, week 4, 8-week Follow-up
Pain	Bodily pain subscale of Short Form-36 (Håvard Loge & Kaasa, 1998).	Baseline, 8-week Follow-up
	Pain Visual Analogue Scale	Pre and post exercise session
Exertion	Rating of Perceived Exertion	Pre and post exercise session
Attention	Focus of Attention	Pre and post exercise session
Affect	The Feeling Scale (FS) (Hardy & Rejeski, 1989)	Pre and post exercise session
Program Enjoyment and Satisfaction	Program satisfaction and feasibility questions (e.g. "Would you recommend this program to others?")	8-week Follow-up

Table 3

Baseline characteristics of the sample

	Yoga (n = 43) n (%) or M (SD)	Waitlist control (n =43) n (%) or M (SD)
Female	37 (86%)	33 (76.7%)
Age	43 (9.92)	40.56 (11.23)
Race		
Caucasian	29 (67.4%)	31 (72.1%)
African American	5 (11.6%)	5 (11.6%)
Asian	8 (18.6%)	5 (11.6%)
Other	1 (2.3%)	2 (4.7%)
Ethnicity		
Hispanic or Latino	5 (11.6%)	2 (4.7%)
Education		
High school	0	1 (2.3%)
Some college	2 (4.7%)	1 (2.3%)
College	17 (39.5%)	21 (48.8%)
Advanced degree	24 (55.8%)	20 (46.5%)
Employment type		
State Institutional Employees	43 (100%)	42 (97.7%)
Private sector employees	0	1 (2.3%)
Essential worker (pandemic)		
Yes	20 (46.5%)	14 (32.6%)
Annual household income		
Less than $20,000	1 (2.3%)	0
$20,000-$39,999	4 (9.3%)	1 (2.3%)
$40,000-$74,999	18 (41.9%)	12 (27.9%)
$75,000-$99,999	5 (11.6%)	7 (16.3%)
>$100,000	13 (30.2%)	19 (44.2%)
Prefer not to respond	2 (4.7%)	4 (9.3%)
Have health insurance?		
Yes	43 (100%)	43 (100%)
Marital status		
Never married	15 (34.9%)	8 (18.6%)
Married	23 (53.5%)	32 (74.4%)
Divorced	5 (11.6%)	3 (7%)
Number of children		
None	15 (34.9%)	16 (37.2%)
One	8 (18.6%)	4 (9.3%)
Two	11 (25.6%)	19 (44.2%)
>two	9 (20.9%)	4 (9.3%)

Table 3 (cont.)

Diagnosed with heart disease?		
Yes	0	0
Diagnosed with cancer?		
Yes	1 (2.3%)	2 (4.7%)
Diagnosed with diabetes?		
Yes	2 (4.7%)	2 (4.7%)
Currently smoke cigarettes		
Yes	1 (2.3%)	0
Consume >2 (men) or >1 (women) alcoholic drinks daily		
Yes	1 (2.3%)	3 (7%)
Consume less than 3 caffeinated drinks daily		
Yes	28 (65.1%)	23 (53.5%)
Limit high fat foods		
Yes	16 (37.2%)	22 (52.4%)
Avoid added sugars		
Yes	11 (25.6%)	17 (39.5%)
Regularly monitor blood pressure		
Yes	1 (2.3%)	3 (7%)
Keep body weight within the recommended BMI		
Yes	14 (32.6%)	16 (37.2%)
Degree of difficulty with seeing		
None	26 (60.5%)	27 (62.8%)
Slight	15 (34.9%)	14 (32.6%)
Moderate	2 (4.7%)	2 (4.7%)
Degree of difficulty with hearing:		
None	30 (69.8%)	29 (67.4%)
Slight	8 (18.6%)	13 (30.2%)
Moderate	5 (11.6%)	1 (2.3%)
Degree of difficulty with walking:		
None	41 (95.3%)	42 (97.7%)
Slight	2 (4.7%)	1 (2.3%)
Moderate	0	

Table 3 (cont.)

Degree of difficulty with lifting:		
None	41 (95.3%)	40 (93%)
Slight	1 (2.3%)	3 (7%)
Moderate	1 (2.3%)	0
Degree of difficulty with remembering or concentrating:		
None	27 (62.8%)	26 (60.5%)
Slight	13 (30.2%)	15 (34.9%)
Moderate	2 (4.7%)	2 (4.7%)
Unable to do	1 (2.3%)	0
Ever exercised continuously for 6+ months?		
Yes	20 (46.5%)	25 (58.1%)
Ever engaged in yoga?		
Yes	30 (69.8%)	33 (76.7%)
Ever engaged in yoga continuously for 6+ months?		
Yes	3 (10%)	7 (21.2%)
Ever engaged in other mind-body practices?		
Yes	21 (48.8%)	20 (46.5%)
Ever engaged in other mind-body practices continuously for 6+ months?		
Yes	4 (9.3%)	4 (9.3%)
Fitbit steps (7-day average)	6274.22 (3216.42)	5578.26 (3022.58)
Godin leisure-time scale score		11.
Body Mass Index	29.40 (8.41)	29.45 (7.93%)

Note: No significant group differences were observed at baseline, except for annual household income.

Table 4

Average attendance for yoga sessions per week.

Week	Attendance (%, all participants)	Attendance (%, four participants removed)
Week 1	100%	100%
Week 2	96.89%	96.58%
Week 3	79.67%	83.78%
Week 4	81.08%	80.55%
Week 5	75.83%	76.92%
Week 6	73.52%	74.74%
Week 7	74.19%	74.19%
Week 8	75.30%	75.30%

Note. Data after removing four participants is presented, because two participants dropped out and two participants were injured, making them unable to engage in the yoga sessions.

Table 5

Average heart rate and rating of perceived exertion (RPE) for yoga sessions per week.

Week	Heart rate after postures	RPE after postures
Week 1	117.19 (14.75)	3.61 (1.24)
Week 2	122.26 (13.45)	4.18 (1.29)
Week 3	122.51 (13.35)	4.10 (1.49)
Week 4	117.80 (23.67)	3.97 (2.42)
Week 5	126.55 (15.28)	4.28 (1.55)
Week 6	121.24 (12.72)	3.71 (1.26)
Week 7	127.29 (11.87)	4.55 (1.81)
Week 8	119.51 (13.29)	3.91 (1.50)

Table 6

Cognitive measures by group.

Measure	Baseline		Follow-up	
	Waitlist control M (SD)	Yoga M (SD)	Waitlist control M (SD)	Yoga M (SD)
Digit span forward*	9.39 (2.26)	9.27 (1.86)	9.16 (2.13)	9.84 (1.99)
Digit span backward*	6.32 (2.15)	6.41 (2.18)	6.11 (2.70)	7.30 (3.05)
DSST	87.27 (18.07)	87.37 (16.68)	95.22 (19.78)	96.36 (19.86)
Stroop congruent reaction time	819.41 (146.59)	787.16 (129.15)	775.74 (153.30)	742.12 (109.54)
Stroop incongruent reaction time	943.62 (168.26)	915.74 (144.86)	887.14 (175.51)	848.84 (129.73)
Stroop cost score	15.33 (6.95)	16.70 (8.41)	14.64 (8.65)	14.54 (8.83)
Task switching cost score	76.96 (86.06)	99.86 (99.96)	70.31 (83.16)	88.23 (115.25)
Task-repeat reaction time	722.79 (199.40)	694.19 (164.35)	688.88 (197.01)	617.81 (142.42)
Task-switch reaction time	799.74 (233.11)	794.02 (213.91)	758.65 (213.38)	707.44 (185.62)
Task total reaction time	755.56 (216.28)	742.56 (172.69)	725.58 (202.38)	670.01 (151.63)

*Significant group difference ($p < .05$)

Table 7

Psychosocial and physical activity measures by group.

Measure	Baseline		8-week follow-up	
	Waitlist control M (SD)	Yoga M (SD)	Waitlist control M (SD)	Yoga M (SD)
STAI*	40.41 (11.25)	40.53 (9.76)	39.36 (11.96)	34.97 (10.34)
HADS-A*	8.13 (3.42)	8.51 (3.90)	8.14 (3.75)	6.36 (2.95)
HADS-D*	6.62 (3.32)	7.46 (3.63)	6.31 (3.51)	5.74 (3.48)
Stress Visual Analog*	35.04 (20.14)	48.14 (23.85)	37.50 (24.93)	25.41 (20.28)
PSS	18.74 (6.11)	19.25 (6.21)	17.62 (6.75)	16.48 (5.89)
BJSQ	37.04 (5.22)	36.39 (6.64)	37.43 (6.03)	35.49 (7.18)
Covid emotion	4.79 (1.22)	5.05 (.90)	4.77 (1.07)	4.60 (1.03)
Covid lonely	5.04 (1.37)	4.87 (1.24)	4.74 (1.27)	4.78 (1.55)
YSE				
Total*	67.52 (21.14)	72.22 (16.90)	62.54 (21.32)	74.84 (19.38)
Postures*	64.94 (22.51)	70.58 (18.42)	60.97 (23.48)	74.17 (20.36)
Breathing*	67.67 (23.03)	72.69 (18.74)	62.93 (21.61)	74.83 (20.87)
Meditation*	70.93 (20.68)	73.64 (17.59)	63.87 (23.05)	76.50 (17.82)
LSE	66.12 (28.30)	67.98 (29.28)	49.46 (30.53)	50.66 (28.57)
BARSE	57.89 (24.32)	60.93 (26.12)	47.11 (22.41)	46.38 (26.60)
PASR				
Total*	30.39 (8.97)	30.38 (9.24)	30.74 (8.05)	35.92 (7.64)
Self-monitoring	5.93 (2.21)	5.74 (2.17)	6.31 (2.08)	6.76 (1.91)
Goal-setting*	5.34 (2.11)	5.19 (2.07)	5.10 (2.02)	6.09 (1.99)
Social support	3.11 (1.77)	3.37 (1.52)	3.21 (1.71)	3.62 (1.63)
Reinforcement	6.69 (2.09)	6.44 (2.06)	6.92 (1.91)	7.24 (1.85)
Time management*	4.90 (1.93)	5.08 (2.11)	5.04 (2.05)	6.62 (1.88)
Relapse prevention*	4.39 (2.13)	4.56 (1.87)	4.18 (2.11)	5.50 (2.18)
MOEES				
Physical	23.55 (3.56)	23.81 (3.31)	23.92 (3.46)	23.84 (3.09)
Self-evaluative	20.09 (3.16)	21.28 (2.82)	20.34 (2.90)	20.33 (3.21)
Social	10.04 (3.02)	10.83 (2.87)	10.53 (3.11)	10.25 (3.66)
Mindfulness	3.67 (.73)	3.50 (.84)	3.69 (.82)	3.74 (.81)
PANAS				
Positive*	28.23 (7.68)	28.60 (7.52)	29.57 (8.68)	33.07 (6.98)
Negative*	19.81 (6.66)	20.85 (5.92)	20.48 (5.85)	17.89 (4.30)
Optimism	2.14 (.50)	2.18 (.56)	2.14 (.56)	2.28 (.57)

Table 7 (cont.)

Self-compassion				
Total*	2.96 (.67)	2.99 (.59)	2.98 (.68)	3.29 (.68)
Self-kindness*	2.82 (.84)	2.81 (.65)	2.73 (.80)	3.10 (.71)
Self-judgement*	2.82 (.85)	2.71 (.80)	2.75 (.85)	3.23 (.77)
Common humanity	3.12 (.92)	3.14 (.71)	3.22 (.97)	3.31 (.85)
Isolation	2.91 (.90)	3.18 (.91)	3.04 (1.06)	3.36 (1.00)
Mindfulness	3.17 (.69)	3.23 (.71)	3.19 (.65)	3.40 (.79)
Over-identification	2.97 (.84)	2.99 (.96)	3.09 (.87)	3.34 (.89)
MAIA				
Noticing	2.79 (.98)	3.01 (1.05)	2.79 (.99)	3.03 (.84)
Not-distracting*	2.02 (.85)	1.79 (.75)	2.03 (.74)	2.22 (1.10)
Not-worrying*	2.86 (.90)	2.96 (.93)	2.67 (.89)	3.08 (.88)
Attention regulation	2.73 (.85)	2.78 (.85)	2.62 (.78)	2.87 (.75)
Emotional awareness	2.95 (.89)	3.23 (.91)	3.02 (.90)	3.24 (.95)
Self-regulation*	2.55 (.97)	2.66 (.92)	2.54 (.85)	3.10 (.71)
Body listening	1.80 (1.07)	2.05 (.91)	1.91 (1.06)	1.91 (1.09)
Trusting*	2.65 (1.20)	3.03 (1.08)	2.64 (1.25)	3.44 (1.02)
GLTEQ				
Total	12.09 (12.19)	10.68 (10.54)	18.97 (14.04)	21.56 (13.66)
Frequency item*	.87 (1.07)	.73 (1.02)	1.27 (1.28)	1.88 (1.63)
Bodily changes				
Physical*	-.17 (.51)	-.06 (.65)	-.06 (.71)	.49 (.59)
Mental	.02 (.89)	.20 (.85)	.33 (.83)	.56 (.84)

*Significant group difference (p <.05)

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APPENDIX A: IRB APPROVAL LETTER

I ILLINOIS

OFFICE OF THE VICE CHANCELLOR FOR RESEARCH & INNOVATION
Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Approval: New Submission

January 30, 2021

Principal Investigator	Sean Mullen
CC	Madhura Abhay Phansikar Adan Taggart John Adamek Imani Canton Amelia Woods
Protocol Title	*Testing the impact of flow-based, moderate-intensity yoga on executive functioning and stress among low active working adults having symptoms of stress*
Protocol Number	21584
Funding Source	Unfunded
Review Type	Expedited 4, 7
Status	Active
Risk Determination	No more than minimal risk
Approval Date	January 30, 2021
Closure Date	January 29, 2026

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Institutional Review Board (IRB) has reviewed and approved the research study as described.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46.
- Using the approved consent documents, with the footer, from this approved package.
- Requesting approval from the IRB prior to implementing modifications.
- Notifying OPRS of any problems involving human subjects, including unanticipated events, participant complaints, or protocol deviations.
- Notifying OPRS of the completion of the study.

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
IORG0000014 • FWA #00008584
217.333.2670 • irb@illinois.edu • oprs.research.illinois.edu

Informed Consent Document and Technology Agreement

Please read and complete this consent form and technology agreement.

You are being asked to participate in a voluntary research study. The purpose of this study is to test the efficacy of an 8-week intervention involving Yoga or a waitlist control group, among inactive adults experiencing symptoms of psychosocial stress. Participating in this study will involve the completion of an 8-week intervention (yoga or waitlist control), remote baseline and post-intervention assessments, and wearing a Fitbit for the duration of the study. Risks related to this research include the possibility of minimal discomfort or injury due to exercise; benefits related to this research include the possibility of medical or health benefits, such as increased energy and reduction in stress levels

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Principal Investigator Name and Title: Sean P. Mullen, PhD, Associate Professor.
Department and Institution: Department of Kinesiology and Community Health at the University of Illinois at Urbana-Champaign
Contact Information: Freer Hall 906 S. Goodwin Ave, Room 227, Urbana, IL 61801 Phone: 217-300-7484 IRB Number:

Why am I being asked?

You are being asked to be a participant in a research study about the effects of an intervention involving Yoga, specifically, moderate-intensity flow-based yoga movements such as sun salutations, or a waitlist control group. The purpose of this research is to test the efficacy of the intervention (Yoga or control group), delivered remotely using a technology medium, among low active full-time working adults experiencing symptoms of psychosocial stress. You have been asked to participate in this research because you are a full-time working adult between the ages of 18-64, are currently low active, report having some symptoms of psychosocial stress, own a smartphone, and have access to a laptop/desktop. Approximately 90 participants will be involved in this research at the University of Illinois at Urbana-Champaign.

Your participation in this research is voluntary. Your decision whether or not to participate will not affect your current or future dealings with the University of Illinois at Urbana-Champaign. If you decide to participate, you are free to withdraw at any time without affecting that relationship.
Placement in groups

What procedures are involved?

This study is completely remote. The study includes a two-armed design with an intervention involving remote, technology-based Yoga or a waitlist control, designed for individuals who are inactive and experiencing symptoms of stress. The study will consist of an 8-week intervention, 2 virtual testing appointments, and online questionnaires.
You will be wearing a Fitbit the entire duration of the study. Participants will be randomly selected into one of two groups:

Group 1 (Yoga): Participants randomized into this group will be asked to engage in yoga sessions of 50-55 minutes, 3 times/week, for 8 weeks. For the first 2 weeks, participants will attend 3 group sessions led by an instructor on Zoom. During weeks 3-5., there will be one group session by the instructor, whereas the other sessions will be unsupervised and done by the participant in their own time. The last 3 weeks will be completely unsupervised. Videos will be provided or the unsupervised sessions.

Group 2 (Waitlist control): Participants randomized into this group will be asked to do their regular activities over the 8 weeks. Following completion of the study, they will be provided with the yoga videos. Regardless of group, all participants will undergo a brief remote assessment before and after the intervention. The total time span of your participation in the study will be approximately 10 weeks.

Assessments
All participants, regardless of group placement, will be asked to complete the following questionnaires and procedures, remotely:

- Demographics and medical health history - You will be asked to complete basic demographic information and a medical health history questionnaire at baseline, during the screening and upon enrollment into the study.
- Questionnaires - You will be asked to complete a series of online questionnaires at baseline and follow-up. This should take approximately 30 minutes to complete.
- Physical Activity Tracking- You will be asked to wear an activity tracker, Fitbit Charge 3, for the duration of the intervention. Your data will be stored and tracked. You will be asked to regularly sync the device via smartphone.
- Neuropsychological assessment- You will be asked to complete a series of computerized assessments that examine different aspects of thinking and memory.

All participants will complete the assessments at two time-points: baseline (before you participate in the intervention and post (after you participate in the intervention). study will be approximately 10 weeks.

What are the potential risks and discomforts?

A risk of this research is a loss of privacy (revealing to others that you are taking part in this study) or confidentiality (revealing information about you to others to whom you have not given permission to see this information). However, to the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

Privacy risk during intervention. A part of the intervention involves engaging in yoga through a live video-conferencing platform (Zoom). Participants will be required to keep their camera on during the intervention, so that their movements can be monitored for feedback. This may be a risk to your privacy, such as revealing your home environment, or the identity of your family members (if they happen to be in the camera frame). However please note that we will not be recording participants at any time, rather just monitoring them during the session.

Assessments. Please keep in mind that you may experience a levels of distress about your own psychological well-being when completing the online assessments, as these questions are personal. You may experience some frustration when completing the neuropsychological testing, as these tests are designed to be challenging.

Exercise risks. Although we do not anticipate any major injuries to occur, it is necessary to notify you of some of the potential risks associated with engaging in exercise. When individuals who have been relatively sedentary engage in exercise, there is a chance of incurring minor injuries and/or discomfort due to the intensified use of major muscle groups, but we do not expect any major injuries to occur. If symptoms of extreme fatigue or pain arise at any point during the study, please contact the research staff and your physician if necessary. To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.
The University of Illinois does not provide medical or hospitalization insurance coverage for participants in this research study nor will the University of Illinois provide compensation for any injury sustained as a result of participation in this research study, except as required by law. We strongly suggest that you pay close attention to all safety instructions we provide.

Are there benefits to participating in the research?

You may directly benefit from participation in the research by experiencing increases in health or well-being, but this is not guaranteed. We hope the information learned from this study will benefit inactive adults experiencing psychosocial stress.

What other options are there?

You have the option not to participate in this study.

Will my study-related information be kept confidential?

We will use all reasonable efforts to keep your personal information confidential, but we cannot guarantee absolute confidentiality. When this research is discussed or published, no one will know that you were in the study. But, when required by law or university policy, identifying information (including your signed consent form) may be seen or copied by: a) The Institutional Review Board that approves research studies; b) The Office for Protection of Research Subjects and other university departments that oversee human subjects research; c) University and state auditors responsible for oversight of research.

Will I reimbursed for any expenses or paid for my participation in this research?

Participants will receive a total of $60 for completing all aspects of the study, including engaging in the intervention, and assessments at baseline and post-intervention.

Can I withdraw or be removed from the study?

If you decide to participate, you are free to withdraw your consent and discontinue participation at any time. The Researchers also have the right to stop your participation in this study without your consent if:
They believe it is in your best interests;
You were to object to any future changes that may be made in the study plan;
You are disruptive to the research process;

What if I am an Illinois employee?

Your participation in this research is in no way a part of your university duties, and your refusal to participate will not in any way affect your employment with the university, or the benefits, privileges, or opportunities associated with your employment at the University of Illinois at Urbana-Champaign. You will not be offered or receive any special consideration if you participate in this research.

Will data collected from me be used for any other research?

Your de-identified information could be used for future research without additional informed consent.

Who should I contact if I have questions?

Contact the researchers in the Exercise, Technology, and Cognition Lab using the email address: map7@illinois.edu

- if you have any questions about this study or your part in it,
- if you have questions, concerns or complaints about the research.

What are my rights as a research subject?

If you have any questions about your rights as a participant in this study, please contact the University of Illinois at Urbana-Champaign Office for the Protection of Research subjects at 217-333-2670 or irb@illinois.edu.

Consent

I have read the above information. I have been given an opportunity to ask questions and my questions have been answered to my satisfaction. By signing below, I indicate my consent to be in this research. I will be emailed a copy of this signed and dated form.

1) Participant's Signature

2) Participant's First Name

3) Participant's Last Name

4) Participant's Email

5) Date

Technology Use Agreement * Terms and Conditions

1. Privileges – The use of technology in the Exercise, Technology, and Cognition Laboratory is a privilege, not a right, and inappropriate use will result in a cancellation of those privileges. The principal investigator(s) and research assistants will deem what is inappropriate use according to current policy. The principal investigator(s) of the study retains the right to terminate access and dismiss any research participant's study involvement if such changes have been made.

2. Acceptable use of technology – The role of technology in the Exercise, Technology, and Cognition Laboratory at the University of Illinois is to support research and education. Research participant access to technology resources must be in support of or consistent with these purposes.

a. Use of assigned technology by research participants must fulfill research study requirements.
b. Research technology access should not be offered to friends or family, unless they are active participants enrolled in the same research study.
c. Research participants should handle all research technology with great care.
d. To ensure confidentiality and continued access to all of our electronic accounts and paired devices, we ask that you do not replace or modify any of the account addresses or identification numbers that have been assigned to you.

e. Transmissions of any material in violation of any U.S. or state regulation is prohibited. This includes, but is not limited to: copyrighted material, threatening or obscene material, or material protected by trade secret.

3. Technology loss or damage: As a participant in research conducted by the Exercise, Technology, and Cognition Laboratory, it is your responsibility to keep all technology in a safe and secure location. This includes any equipment worn by you, what is used in the university research laboratory, or that which is stored within your home.

a. Transfer of equipment from university to home: It is expected that research participants will conform to generally accepted procedures to prevent theft (e.g., keep equipment with you at all times; vehicles doors locked; equipment hidden from view). Equipment should not be stored overnight in a participant's vehicle to further prevent theft and any damage from extreme temperatures.
b. Setup and storage of equipment: It is expected that research participants will position all assigned technology out of harm's way (such as extreme hot or cold temperatures, running water, or in the middle of the floor where technology may be stepped on, or on the edge of furniture whereby technology could fall and break).
c. Unsupervised use of lab equipment: It is expected that research participants will not attempt to use any of the equipment stored within the research setting including computers, keyboard controllers, and other machines or devices, unless instructed to do so.
d. Returning equipment: It is expected that research participants will return all equipment in working condition. Although some wear and tear is anticipated to occur, participants should uphold the condition of all equipment to the best of their ability. This includes exergaming consoles (Xbox), iPads, Fitbits, and all peripherals (e.g. cases, controllers, Kinect camera, cables and connectors).

4. Technology Etiquette – The researcher-participant relationship is a professional one, not a social one. We ask that you keep all communications professional in nature and directed towards study participation. You are expected to abide by our standard conventions for technology etiquette, including the following.

a. Do not reveal personal information about yourself or others in your electronic communications.
b. With the exception of emergency situations, we ask that you avoid the use of your own mobile phone during our testing and training appointments.
c. If correspondence with a member of our research staff transpires via text messaging (such as last-minute cancellation of an appointment), participants should aim to end the exchange after the goal of the message has been reached. Any need for longer communications involving additional questions, concerns, or comments should be directed to a research staff member in person.
d. If a member of our research staff attempts to contact a research participant via email or voicemail, it is expected that the participant will reply promptly with clear and specific information (e.g., avoid the use of abbreviations, emoticons, and attempts at humor).
e. Any other guidelines discussed as part of your participation in the study.

Exercise, Technology, and Cognition Technology Use Agreement

I understand and will abide by the above Technology Use Agreement. I further understand that I must return all equipment loaned to me for research purposes. I also understand that any violation of the regulations above is unethical and may constitute a criminal offense. Should I commit any violation, I understand that I am subject to further action according to the University of Illinois policy.

1) Participant's Name

2) Participant's Signature