THE RELATIONSHIP BETWEEN RESTORATIVE YOGA AND EXECUTIVE FUNCTION

by

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A thesis submitted to the Graduate Council of
Texas State University in partial fulfillment
of the requirements for the degree of
Master of Arts
with a Major in Psychological Research
May 2021

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ACKNOWLEDGEMENTS

I would first like to thank my mentor Dr. Crystal Oberle for her encouragement, support, knowledge, and guidance throughout my master's degree. I'm extremely grateful to have her as a mentor. Thank you for always being a breath of fresh air when I would get caught up in the intimidating landscape of academia.

I could not get to where I am now without Dr. Rebecca Deason and Dr. Kristen Tooley for giving me my first opportunities in cognitive research as an undergrad. Your support was invaluable in finding my own research interests. Thank you for giving me the experience I needed to move forward as a confident researcher.

Lastly, I would like to thank my cohort for the support we have given each other in the face of a very unique graduate experience. Having such an accepting loving group of individuals to navigate the growing pains of becoming a graduate student during this time was more than I could have ever asked for. Kristen Sigler, Kennedy Anderson, and Taylor McDonald thank you for sharing this journey with me: I couldn't have done this without your shoulders to cry on and ears to listen.

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ABSTRACT

This study investigated potential differences in executive function among those who practice restorative yoga (*n* = 86), those who practice traditional yoga (*n* = 51), and those with no yoga experience (*n* = 163). The majority of participants were female (90%) and college educated (26% with college credit but no degree, 7% with Associate's degree, 19% with Bachelor's degree, 15% with graduate degree), and their ages ranged from 18 to 72 (*M* = 27.54, *SD* = 12.47). In this online study, after completing a brief survey, participants completed six computerized tests of executive function, two assessing cognitive flexibility (Wisconsin Card Sorting Task and Trail Making Task), two assessing inhibitory control (Stroop Task and Go/No-Go Task), and two assessing working memory updating (N-Back Task with Letters and N-Back Task with Shapes). Data were analyzed with a MANCOVA, controlling for demographic variables that differed between groups. Although the MANCOVA's omnibus test was not significant, the tests of between-subjects effects revealed that the groups significantly differed on the percent of perseverative responses on the Wisconsin Card Sorting Task, with the restorative yoga group performing better than the traditional yoga and control groups (p = .03). These findings suggest that restorative yoga may have a slightly beneficial effect on cognitive flexibility. Regarding the lack of significant group differences on the other

variables, it is important to note that data were collected in the middle of the COVID-19 pandemic, when many of the yoga practitioners may not have been regularly practicing yoga, and perhaps this regular practice is necessary to obtain benefits in executive function.

I. INTRODUCTION

Traditional forms of yoga have been found to improve performance on tasks of executive function and produce corresponding differences in brain structure and activity (Cohen et al., 2018; Gothe et al., 2013, 2018; Luu & Hall, 2016). These findings make yoga a promising therapy for those experiencing deficits in executive function. Traditional forms of yoga, although they have been found to have many cognitive benefits, are not accessible to all populations. Restorative yoga is a form of yoga that does not focus on strength, stamina, and flow, but rather relaxation making it more feasible for sedentary, injured, or older populations (Lapen et al., 2018). Although restorative yoga may be more accessible for some, the effects of restorative yoga on cognitive performance have yet to be investigated.

Executive Function

Executive function involves higher-order cognitive processes that are not stimulus-driven, such as working memory, cognitive flexibility, inhibitory control, abstract thinking, planning, and problem solving (Gothe et al., 2013; Luu & Hall, 2016). As reviewed below, yoga has been associated with improvements in working memory, inhibitory control, and cognitive flexibility. First, working memory, or more specifically the updating of working memory, is the ability to manipulate or transform incoming information to complete a task or solve a problem (Willis & Blaskewicz Boron, 2015). Examples of tests that measure working memory updating are the N-Back Task, the Sternberg Working Memory Task, and the Backward Digit Span Task. Second, cognitive flexibility is the ability to adapt one’s thoughts and behaviors in response to new information or events. Examples of tests that measure cognitive flexibility are the Trail

Making Task and the Wisconsin Card Sorting Task. Finally, inhibitory control is the ability to manage and direct attention while ignoring other stimuli. Examples of tests that can measure inhibitory control are the Flanker Task, the Stroop Task, and the Go/No-Go Task.

Yoga

The average yoga practitioner in the United States (US) is a middle aged, college educated, White woman, of higher socioeconomic status (Park et al., 2015). Moreover, 48% of Americans who practice yoga have a household income of at least $65,000 a year, and 50% of practitioners have a college education. Only 6.1% of Americans reported practicing yoga for their health, despite the various proven mental and physical health benefits such as decreased pain symptoms, improved sleep, reduction in salivary cortisol, and reduced oxidative stress (Ross & Thomas, 2010). Coinciding with these health benefits are the motivations driving yoga practitioners, with health promotion and the prevention of disease being a leading reason for initially turning to yoga (25.5%) and for continuing to practice yoga (38.4%; Park et al., 2019).

The aforementioned demographics of typical yoga practitioners clearly illustrate that traditional yoga is not accessible or compelling to all people in the US. Age, sex, ethnicity, and religious beliefs may deter some individuals from practicing yoga. Moreover, common barriers to yoga practice are transportation, costs, attire, and negative perceptions (Spadola et al, 2020). Oftentimes, yoga classes are offered in more affluent areas or are not accessible by walk or public transportation and are a deterrent for many people in low income areas. Costs for both the classes and for other items (e.g., clothing, yoga mat) associated with yoga may be another deterrent. Attire may be an issue also because some individuals don't want to participate if they feel their attire is too revealing. In addition, negative perceptions vary from yoga being a "woman's" activity to it seeming like a waste of time.

There are many different styles of yoga that vary from relaxing and meditative to powerful flow classes that can feel similar to a workout. Popular forms of yoga are hatha, vinyasa, yin, and hot/bikram. Hatha yoga in the west is usually slow and focuses on basic poses and breathing. Traditionally, "hatha" is simply a term for the yoga postures. Vinyasa yoga is another very common form of yoga that involves coordinating the movement with breathing. Vinyasa can be very intense and powerful and feel similar to a cardio workout and leave you sore the next day. Ashtanga is a traditional form of yoga where individuals practice a set sequence at their own pace. This style has the same poses and flow as vinyasa but is just practiced in a traditional form. Yin yoga is form of yoga that relies on passive stretching and holding postures for long periods of time to get a very deep stretch. It is often mistaken as a very calm form of yoga, but it can become very intense and require meditation to power through the intense stretch. Hot yoga, formerly referred to as Bikram yoga, is a set sequence of postures practiced in a heated room usually from 95-105 degrees Fahrenheit.

Restorative yoga is a form of yoga that focuses on passive stretching and supported postures. Compared to traditional yoga, it focuses more on the meditation aspect than on movement and flow. Restorative yoga practice involves holding passive relaxation postures for a long period of time with the support of various props. Restorative yoga may be a good alternative for older populations, patient populations, and those with injuries. For example, in a study examining the feasibility of a 12-week yoga intervention in cancer survivors comparing adherence to traditional and restorative yoga (Lapen et al., 2018), researchers found that adherence during the 12-week supervised intervention was greater in the restorative yoga group (100% of 20 participants) than in the traditional yoga group (87% of 15 participants). Moreover, adherence to unsupervised yoga practice at home during a 12-week post-intervention period was also greater in the restorative yoga group (85% of 20 participants) than in the traditional yoga group (77% of 15 participants). Although these group differences were not statistically significant with this relatively small sample, the results do offer promise for utilizing a restorative yoga intervention program in ill or injured populations.

Traditional Yoga and Executive Function

Executive function has been studied in previous research comparing the immediate, or acute, effects of yoga. Researchers compared 30 healthy women on the Modified Flanker Task and the N-Back Task after one session of either no exercise, aerobic exercise, or yoga (Gothe et al., 2013). The researchers found that the yoga group had significantly better response accuracy on the Modified Flanker Task than the aerobic exercise group, showing superior inhibitory control. The yoga group also had significantly higher accuracy on all three phases of the N-Back Task, showing superior working memory updating. In another study assessing the acute effects of yoga, researchers found that a hatha yoga session resulted in improved inhibitory control with greater accuracy on the Stroop Task (Luu & Hall, 2017). Note that these results are consistent with those from studies with longer interventions. For example, healthy adults tested before and after 6 sessions of yoga training were found to have significant improvements on two working memory tasks: Digit Span Forward and Digit Span Backward (Brunner et al., 2017).

Yoga intervention has also been studied in the classroom. In a study of self-regulation and grade point average (GPA) in high school students, researchers investigated whether self-regulation skills learned in yoga transfer to the classroom (Hagins & Rundle, 2016). Researchers studied self-regulation's effect on GPA by comparing mean GPA in students taking 49 yoga classes versus 49 physical education (PE) classes. Self-regulation and executive functioning are closely related to the ability to focus on tasks, reading, math, and linguistics (NICHD Early Child Care, Research Network, 2003). They hypothesized that if self-regulation skills learned in yoga transfer to the classroom then students in the yoga group should have a greater improvement in GPA compared to the PE group. They found that students who participated in all 49 yoga classes had a significantly improved mean GPA compared to the 49 PE classes. There were no significant differences in the groups when accounting for individuals who did not complete all of the classes.

Yoga has also been found to improve executive function in various cognitively vulnerable populations, such as the elderly. In older adults, an 8-week hatha yoga intervention was successful at improving working memory updating on the N-Back Task and cognitive flexibility on a task switching task (Gothe et al., 2014). Similarly, in older adults with mild cognitive impairment, a 12-week Kundalini yoga intervention resulted in improved cognitive flexibility on the Trail Making Task and inhibitory control on the Stroop Task (Eyre et al., 2017), with these improvements being comparable to those resulting from memory enhancement training, which is considered a "gold standard" technique for enhancing cognitive function in this population (Flak et al., 2014). As a partial explanation for these benefits of yoga on executive function in the elderly, research reveals that older women who practiced yoga for at least 8 years when compared to matched controls were found to have greater cortical thickness in the left prefrontal cortex (Afonso et al., 2017).

The positive impacts of yoga have also been found in children with impaired cognitive function. One such vulnerable population is those diagnosed with attention-deficit/hyperactivity disorder (ADHD), whose attention deficits are directly tied to impaired executive functioning. In a sample of preschool children ADHD, a 6-week yoga intervention was successful in improving inhibitory control performance on the Go/No-Go Task (Cohen et al., 2018). As another example of yoga's impact, other researchers found that a 3-month yoga intervention resulted in improved inhibitory control and cognitive flexibility in orphans, who experience early life stress and correspondingly have reduced executive functioning (Purohit & Pradhan, 2017).

As reviewed above, yoga practice has been shown to improve cognitive performance, but the corresponding effects on the brain have not been examined as thoroughly (Gothe et al., 2013; Hagins & Rundle, 2016; Luu & Hall, 2016). One study sought to explore the neural correlates of cognitive improvements among yoga practitioners (Gothe et al., 2018). They compared MRI brain scans of 13 experienced yoga practitioners to 13 sex-matched controls, while doing a Sternberg Working Memory Task. While there were no differences in reaction times or accuracy between the two groups, the yoga practitioners had significantly more gray matter in the left hippocampus versus the control. This area of the brain also experiences age-related changes, suggesting that a yoga intervention could mitigate age-related cognitive decline (Raz & Rodrigue, 2006). The researchers also found less activation in the dorsolateral prefrontal cortex of the experienced yoga practitioners during the encoding phase of the task. The dorsolateral prefrontal cortex and hippocampus are both involved in cortical arousal and emotional regulation (Milad et al., 2007). This difference could possibly be explained by yoga practitioners having increased efficiency of the dorsolateral prefrontal cortex, because of their ability to self-regulate, a key aspect in improving cognition (Moore & Malinowski, 2009).

In healthy populations, yoga has been shown to be equally effective or superior to exercise on all outcomes examined except those involving physical fitness (Ross & Thomas, 2010). Yoga has been found to positively effect heart rate variability, blood glucose, blood lipids, salivary cortisol and oxidative stress. Moreover, low intensity exercises have proven to lower cortisol while high intensity exercise increases it, and this could explain why low intensity yoga positively effects the hypothalamic-pituitary-adrenal (HPA) axis response to stress. The HPA axis and the sympathetic nervous system are both activated in response to stressors, releasing cortisol and catecholamines. One study wanted to observe if salivary cortisol was predictive of superior executive function (Gothe et al., 2016). They had two groups: one yoga and one stretching and strengthening. After an 8-week intervention, they had the participants complete a neuropsychological battery that acted as a stressor, then complete two working memory measures (running span and n-back) and a task-switching measure. In response to the stressor, the yoga group had an attenuated cortisol response corresponding with lower reported anxiety than the stretching-strengthening group. The attenuated cortisol response to stressor in the yoga group was a predictor for improved accuracy on most of the working memory outcomes. Elevated cortisol response was associated with poor accuracy on the task-switching outcomes in the stretching and strengthening group. These results offer biological evidence that the ability to self-regulate improves executive function.

Meditation and Executive Function

Meditation is a key component of all yoga practice. Pranayama is a term used in yoga that is referring to bringing your attention to your breathing, a common form of mediation. A traditional yoga class would typically have a set of poses and end with about 10 minutes of meditation usually in savasana, corpse pose. Corpse pose is one of many restorative yoga poses. A restorative yoga class would place more emphasis on meditation in restorative yoga poses that are held for long periods of time. These poses are meant to relax the body and find stillness in the body to aid in stillness of the mind. This stillness is allowing for deeper meditation than an energetic pose one would do in a traditional class, such as head stand.

Meditation interventions, ranging from single sessions to longer 6-week programs, have been shown to be effective at enhancing cognition. On the briefer side, a single session of mindfulness meditation has been associated with greater attention performance compared to baseline on such measures as the Stroop Task (Greif & Kaufman, 2021; Luu & Hall, 2017). Next, as little as four days of mindfulness meditation training (20min/day) has been found to improve performance on multiple tasks of executive function including the Symbol Modalities Test, Controlled Oral Word Association Task, and N-Back Task (Zeidan et al., 2010). Finally, and not surprisingly, longer interventions have also been associated with improvements in executive function, with a 1-month meditation intervention leading to improved inhibitory control on a response inhibition task (Zanesco et al., 2013) and a 6-week meditation intervention leading to improved executive function assessed with survey measures (Bruin et al., 2016). Note that both the focused attention and open monitoring forms of meditation have been shown to improve executive control, whereas open monitoring additionally seems to improve attention orienting (Tsai & Chou, 2016).

Cognitively vulnerable populations have also found benefits in executive functions through meditation. First, older adults who are expert meditators, when compared to older adults naïve to mediation, performed significantly better on the Attentional Network Task that involves cue detection and a flanker-type paradigm (Sperduti et al., 2016). Not only did they perform better than the older adults with no meditation experience, they performed the same as the young adults that were naïve to mediation. Second, in a small sample of children newly diagnosed with ADHD, an 8-week mindfulness meditation intervention significantly improved ADHD symptoms (Huguet et al., 2017). The alleviation of symptoms may be related to improvement of executive function. For instance, Iranian female adolescents with ADHD after six sessions of mindfulness meditation training significantly improved performance on a task of inhibitory control, the Stroop Task (Kiani et al., 2017). In adults with ADHD 8-weeks of meditation intervention improved self-report measures of ADHD and EF but there was no significant effect on task of EF (Taddei et al., 2017). Adults with ADHD may need longer intervention than children.

Regarding the physiology underlying the executive function benefits of meditation, long-term meditators have been studied with event-related potentials (ERP) to examine how mediation effects the attentional control network (Jo et al., 2016). Meditators in comparison to controls performed better on the Attentional Network Task, and they did not have change in amplitude at P3 with congruent and incongruent trials of the task, as seen in the control group. In previous studies, lack of modulation through P3 has been associated with dysfunctional inhibition or target detection (Neuhaus et al., 2010). Another study compared controls and those doing a 10-min mindfulness for 16 weeks found a similar result (Moore et al., 2012).

Purpose and Hypotheses

The previously reviewed literature reveals that both traditional yoga and meditation are associated with improvements in executive function. What has not yet been investigated is whether restorative yoga is also associated with such improvements. The current study will examine three aspects of executive function (cognitive flexibility, inhibitory control, and working memory updating) with six different neuropsychological tests, in those who practice restorative yoga, those who practice traditional yoga, and those who do not practice any yoga. Given that yoga has shown to be more effective than aerobic exercise and resistance training because of the mind-body aspect of it (Gothe et al., 2013), both restorative and traditional yoga practitioners should perform better than those who do not participate in any form of yoga. Moreover, given restorative yoga's increased emphasis on the meditative aspect, restorative yoga practitioners should perform better than traditional yoga practitioners.

II. METHOD

Design

This study used a quasi-experimental research design, examining differences in executive function among preexisting groups of restorative and traditional yoga practitioners. The quasi-independent variable was yoga experience with three levels: restorative yoga, traditional yoga, and control. The restorative yoga group included individuals who have practiced restorative yoga for at least 10 sessions. The traditional yoga group included individuals who have practiced any style of yoga except restorative for at least 10 sessions. The control group included individuals who have never practiced yoga.

Participants

Participants were adults recruited through the Texas State SONA system, emails distributed by yoga teachers, flyers posted in gyms and yoga studios, and an Instagram advertisement. Participants recruited through SONA were compensated with two SONA credits, that corresponds to a study taking 30-60 minutes to complete. Participants recruited through emails were compensated through a $10 Amazon gift card. Participants recruited through flyers and Instagram advertisement were entered into a drawing to win one of 13 gift cards for Amazon.com, each in the amount of $50. Exclusion criteria were not completing the full study, having below 50% accuracy on any individual task (indicating a lack of effort), or not meeting the requirements to belong to one of the three yoga experience groups.

Of the participants meeting the aforementioned inclusionary criteria, there were 163 participants in the no-yoga control group, 51 participants in the traditional yoga group and 86 participants in the restorative yoga group. Regarding demographics, the majority were female (90%; 10% male), and their ages ranged from 18 to 72 (M = 27.54, SD = 12.47). For education, 31% reported that a high school diploma or equivalent was their highest level, 26% reported college credit without a degree, and 41% reported earning a college degree (7% Associate's degree, 19% Bachelor's degree, 13% Master's degree, 2% doctoral degree). For activity level, assessed as time spent doing moderate or strenuous aerobic exercise, 24% reported less than one hour per week, 33% reported 1-2 hours per week, 32% reported 3-6 hours per week, and 11% reported 7 or more hours per week. In addition, the vast majority (95%) indicated that they did not compete in any organized sports. For weight, the body-mass index (BMI) of participants ranged from 15.81 to 46.68 (M = 24.85, SD = 5.19).

Procedure and Materials

Participants were given an online survey via Qualtrics about basic demographic information and yoga experience. The survey began by asking participants to read over a consent document, and upon consent, participants continued to the survey. The survey then asked questions assessing demographic information including age, education, gender, weight and height (to calculate BMI), and competitive athlete status. Additionally, participants were asked about how much time they spend during a typical 7-day period doing moderate or strenuous aerobic exercises with the heart beating rapidly and doing strength training exercises. For both questions, the response options were as follows: none or less than 1 hour per week, 1-2 hours per week, 3-6 hours per week, 7-10 hours per week, 11-14 hours per week, and 15 or more hours per week. Next, participants were asked about their typical daily consumption of vegetables, fruits, meats, and sweets.

For all four questions, the response options were as follows: none, 1-2 servings per week, 1-2 servings every other day, 1-2 servings per day, 3-4 servings per day, and 5 or more servings per day. Finally, participants were asked questions relating to their yoga experience including whether they practice yoga, as well as how many sessions they have done of traditional yoga, and restorative yoga. After clicking on a link to complete the survey, participants were then directed to an online computerized version of six tasks of executive function using the Inquisit software (millisecond.com). Two of these tasks assessed cognitive flexibility, two assessed inhibitory control, and two assessed working memory updating.

Wisconsin Card Sorting Task

The Wisconsin Card Sorting Task (WCST; Grant & Berg, 1948) is one test of cognitive flexibility. For the WCST, participants are given a deck of 128 cards to sort into four piles marked by the following cards: one red triangle, two green stars, three yellow crosses, and four blue circles. Participants are never told the sorting rule (i.e., sorting by number, color, or shape); instead, the word "correct" appears when they place the card in the correct pile, and the word "wrong" appears when they place the card in an incorrect pile. The sorting rule changes after 10 consecutive correct responses, and the test ends when the participant either runs out of cards or successfully completes six categories: two for each sorting rule. The variables for this test are total errors (number of incorrect responses), percent perseverative errors (percent of errors that were perseverative), percent perseverative responses (percent of responses that were perseverative), categories completed (number of the six sequences of 10 consecutive correct responses that were completed), failure to maintain set (number of errors made once a rule is known, as evidenced by five consecutive correct responses), trials to complete first category (number of trials taken to complete the first sequence of 10 consecutive responses), and learning to learn index (average difference in percent errors between successive categories, with positive values reflecting fewer errors on the next category). Greater cognitive flexibility would be evident with fewer perseverative errors and responses.

Trail Making Task

The second measure of cognitive flexibility that was used is the Trail Making Task (TMT; Reitan, 1955). For the TMT, participants are instructed to move the computer mouse to draw lines from node to node as fast as possible. Trail A includes numbers only, with lines being drawn from 1 to 2, 2 to 3, and so on; whereas Trail B includes numbers and letters, with lines being drawn from 1 to A, A to 2, 2 to B, and so on. For each trail, the variables are errors (number of errors made) and completion time (time taken to complete the trail). Greater cognitive flexibility would be evident with fewer errors and lower completion time on Trail B.

Stroop Task

One of the tests for inhibitory control that was used is the Stroop Task (Stroop, 1935). For the Stroop Task, on each trial, a word in a certain color font is presented on the screen. Participants are instructed to indicate the font color, ignoring what the word means, by pressing one of the following keys: ‘D’ for red, ‘F’ for green, ‘J’ for blue, or ‘K’ for black. Sometimes the word is a color word in the same font such as the word ‘RED’ typed in red font (i.e., congruent trial), sometimes the word is a color word in a different font such as the word ‘GREEN’ typed in red font (i.e., incongruent trial), and sometimes the word is a non-color word such as the word ‘TABLE’ typed in red font (i.e., control trial). The variables for this task are percent error and response time (RT) on congruent trials, percent error and RT on incongruent trials, and percent error and RT on control trials. Greater inhibitory control would be evident with fewer errors and lower RT on incongruent trials.

Go/No-Go Task

The Go/No-Go Task (Fillmore et al., 2006) was used as the second test of inhibitory control. For the Go/No-Go Task, on each trial, a white rectangle appears on the screen and then turns either green or blue. Participants are instructed to press the spacebar key as quickly as possible when the rectangle turns green (i.e., Go trial), and to not respond if the rectangle turns blue (i.e., No-Go trial). The variables for this task are percent error on Go trials (i.e., omission errors whereby participants fail to respond), percent error on No-Go trials (i.e., commission errors whereby participants incorrectly respond), and RT on Go trials. Greater inhibitory control would be evident with fewer errors on No-Go trials.

N-Back Task with Letters

The N-Back Task with Letters (Ragland et al., 2002) was one task used to measure working memory updating. For the N-Back Task with Letters, on each trial, a series of white letters on a black background are individually presented on the screen. Participants are instructed to press the ‘A’ key each time the current letter is the same as the letter presented n positions back. This task included 2-back, 3-back, and 4-back trials. The variables for this task are hit rate (proportion of correct responses – correctly pressing the ‘A’ key when the current letter is the same as the letter presented n positions back), hit RT (mean RT for correct responses), false alarm (FA) rate (proportion of error responses – incorrectly pressing the 'A' key when the current letter is not the same as the letter presented n positions back), FA RT (mean RT for incorrect responses), and d' (sensitivity measure calculated as follows: [hits – FA]/total trials). Greater working memory updating would be evident with a greater hit rate, lower FA rate, and greater d' value.

N-Back Task with Shapes

The N-Back Task with Shapes (Jaeggi et al., 2010) was used as the second measure of working memory updating. For the N-Back Task with Shapes, on each trial, a series of abstract yellow shapes on a black background are individually presented on the screen. Participants are instructed to press the 'A' key each time the current shape is the same as the shape presented n positions back. This task included 2-back, 3-back, and 4-back trials. As with the previous task, the variables for this task are hit rate, hit RT, FA rate, FA RT, and d'. Greater working memory updating would be evident with a greater hit rate, lower FA rate, and greater d' value.

Statistical Analyses

Data were analyzed with a preliminary MANOVA and a subsequent MANCOVA, for which the between-subjects variable was yoga experience with three groups: no-yoga control group, traditional yoga practitioners, and restorative yoga practitioners. For the preliminary MANOVA to assess any group differences in the demographic and health-related variables, the dependent variables were age, education level, BMI, aerobic exercise, strength training exercise, vegetable consumption, fruit consumption, meat consumption, and sweets consumption. For the MANCOVA to assess group differences in executive function, the dependent variables were all measures of performance for the six different executive function tests. The covariates controlled for in this analysis were any of the demographic or health-related variables that significantly differed between groups (based on the preliminary MANOVA). Tukey's post hoc test will be used to determine specific differences between groups. Eta-squared will be reported as an effect-size measure, with values equal to or greater than .01 interpreted as a small effect, values equal to or greater than .06 interpreted as a medium effect, and values equal to or greater than .14 interpreted as a large effect.

III. RESULTS

The initial MANOVA revealed significant group differences on the demographic and health-related variables, Wilks' $\Lambda = 0.34$, $F(18, 576) = 23.21$, $p < .001$. As presented in Table 2, the tests of between-subjects effects revealed that the groups differed on all variables except BMI and consumption of sweets. All significant variables were then entered as covariates in the subsequent MANCOVA.

Table 1

Participant Demographics on Significant Continuous Covariates

	Control	Yoga	Restorative
Median Age	18	30	38
Average hours aerobic exercise /week	2.06	2.57	2.80
Average hours strength training /week	1.70	2.27	2.18
Average servings of vegetable /week	2.78	4.08	4.51
Average servings fruit /week	2.88	3.75	3.85
Average servings meat /week	3.42	3.18	2.91

Table 2

MANOVA Tests of Between-Subjects Effects

	F	*p*	η_p^2
Age	118.95	<.001	.45
Education	197.27	<.001	.57
BMI	0.07	.94	.00
Aerobic exercise	17.10	<.001	.10
Strength training	10.75	<.001	.07
Vegetable consumption	89.75	<.001	.38
Fruit consumption	32.93	<.001	.18
Meat consumption	4.64	.01	.03
Sweet consumption	0.13	.88	.00

MANCOVA results showed no significant differences between groups on executive function performance, Wilks' $\Lambda = 0.75$, $F(60, 348) = 0.88$, $p = .72$. Although the omnibus test was not significant, the tests of between-subjects effects (see Table 3) revealed a significant difference between groups on percent perseverative responses on the WCST, $F(2, 203) = 3.64$, $p = .03$, $\eta_p^2 = .04$. The restorative yoga group ($M = 9.50$, $SD = 4.12$) had fewer perseverative responses than the traditional yoga ($M = 10.95$, $SD = 5.80$) and no yoga ($M = 11.71$, $SD = 4.74$) groups. This same trend was found for the percent perseverative errors for the WCST, although the difference did not reach statistical significance, $F(2, 203) = 1.90$, $p = .15$, $\eta_p^2 = .02$.

Table 3

MANCOVA Tests of Between-Subjects Effects

	F	*p*	η_p^2
WCST			
Total errors	1.73	.18	.02
% perseverative errors	1.90	.15	.02
% perseverative responses	3.64	.03	.04
Completed categories	2.46	.09	.02
Failure to maintain set	1.38	.25	.01
Trials to complete first category	0.91	.41	.01
Learning to learn index	2.81	.06	.03
TMT			
Trail A errors	0.65	.53	.01
Trail A completion time	2.32	.10	.02
Trail B errors	0.01	.99	.00
Trail B completion time	0.01	.99	.00
Stroop Task			
Congruent % error	1.11	.33	.01
Incongruent % error	0.30	.74	.00
Control % error	0.77	.46	.01
Congruent response time	0.35	.70	.00
Incongruent response time	0.21	.82	.00
Control response time	0.26	.77	.00
Go/No-Go Task			
Go trials % error	0.38	.69	.00
No-Go trials % error	1.02	.36	.01
Go trials response time	0.70	.50	.01
N-Back Task with Letters			
Hit rate	0.16	.85	.00
Hit rate response time	0.32	.73	.00
FA rate	0.26	.77	.00
FA rate response time	2.41	.09	.02

d prime	0.16	.85	.00
N-Back Task with Shapes			
Hit rate	1.11	.33	.01
Hit rate response time	1.22	.30	.01
FA rate	1.28	.28	.01
FA rate response time	3.18	.04	.03
d prime	1.30	.27	.01

IV. DISCUSSION

Discussion of Results and Theoretical Implications

The current study explored whether traditional yoga practitioners, restorative yoga practitioners, and those with no yoga experience differ on three aspects of executive function (cognitive flexibility, inhibitory control, and working memory updating). Past research on the acute effects of traditional yoga on executive function have found that individual yoga sessions and lengthier yoga interventions lead to significant improvements in cognitive flexibility (Eyre et al., 2017; Purohit & Pradhan, 2017), inhibitory control (Cohen et al., 2018; Eyre et al., 2017; Gothe et al., 2013; Luu & Hall, 2017; Purohit & Pradhan, 2017), and working memory updating (Brunner et al., 2017; Gothe et al., 2013, 2014). By extension, it was expected that traditional yoga practitioners would perform better than those with no yoga experience on all measures of executive function in the current study. Although past research has not examined the effects of restorative yoga on executive function, restorative yoga places greater emphasis on meditation than traditional yoga, and meditation sessions and interventions have been shown to lead to improvements in executive function (Bruin et al., 2016; Greif & Kaufman, 2021; Kiani et al., 2017; Luu & Hall, 2017; Tsai & Chou, 2016; Zeidan et al., 2010; Zeidan et al., 2010). By extension, it was expected that restorative yoga practitioners would perform better than those with no yoga experience on all measures of executive function in the current study.

In contrast to the aforementioned hypotheses, the omnibus MANCOVA test reveals no significant group differences on executive function performance. Yet, the between-subjects effects revealed a trend showing restorative yoga practitioners outperforming the traditional and no yoga groups on the WCST, with the restorative yoga practitioners having fewer perseverative responses (p = .03) and errors (p = .15), completing more categories (p = .09), and having a higher learning index (p = .06). The groups did not significantly differ in performance on the other five tasks: TMT, Stroop Task, Go/No-Go Task, N-Back Task with Letters or the N-Back Task with Shapes. These results are inconsistent with the findings from past research showing improvements in executive function with acute and long-term yoga practice (Brunner et al., 2017; Cohen et al., 2018; Eyre et al., 2017; Gothe et al., 2013, 2014; Luu & Hall, 2017; Purohit & Pradhan, 2017).

An important point worth noting, however, is that all data were collected in Fall 2020, during the COVID-19 pandemic when many yoga studios were closed for health concerns. These closures may have disrupted yoga practice for many people, and the research questionnaire did not account for the recency of the yoga experience. As such, the lack of significant group differences may possibly be attributed to the disruption of normal yoga practice, presuming that the benefits of yoga practice on executive function do not persist if the practice is interrupted. In fact, the prior studies showing improved executive performance were predominantly those examining the acute effects of either individual yoga sessions or lengthier yoga interventions (Brunner et al., 2017; Cohen et al., 2018; Eyre et al., 2017; Gothe et al., 2013, 2014; Luu & Hall, 2017; Purohit & Pradhan, 2017), not those examining naturally occurring group differences as was done in the current study. This may suggest that the benefits of yoga are immediate but brief, and that regular yoga practice may be necessary to maintain cognitive benefits. Many people who would normally practice yoga in a studio may not have the knowledge, equipment, motivation, or confidence to practice without an instructor during quarantine.

Strengths, Limitations, and Directions for Future Research

The current quasi-experimental research was strengthened with a respectable sample of over 50 traditional yoga practitioners, over 80 restorative yoga practitioners, and over 160 participants in the control group without any yoga experience. While the vast majority of studies on yoga and executive function have been experimental and explored the impact of either acute yoga sessions or lengthier yoga interventions, more quasi-experimental studies are needed to determine whether there are any differences in pre-existing groups of yoga practitioners. With the experimental research, if an individual takes a cognitive test before and after an intervention, the participant may believe the purpose of intervention is to improve on the task, and these expectations may influence their thoughts and behaviors during the intervention that could potentially impact later test performance. However, this future quasi-experimental research should account for the recency and consistency of yoga practice to determine if the effects on executive function are sustained without constant practice. Additionally, this future research should include a meditation-only control group of participants with meditation experience but without any yoga experience. Unfortunately, there were only five such participants who completed the current study, which was insufficient for conducting statistical analyses.

The current study was also strengthened by the inclusion of two tests for each aspect of executive function being tested: cognitive flexibility, inhibitory control, and working memory updating. With the two cognitive flexibility tests, for example, we were able to determine if the groups differed on the more challenging WCST, even if they did not differ on the simpler TMT that could perhaps be limited by ceiling effects in such a well-educated sample. Whereas all six tests in the current study are well-established objective performance-based assessments that are presumably immune to social-desirability biases, many researchers argue that they are less ecologically valid than self-report tests because they measure executive function in very controlled artificial environments that do not represent more complex environments in daily life where behavior is impacted by a multitude of factors including emotional distress (Blijd-Hoogewys et al., 2014; Gioia & Isquith, 2004; Isquith et al., 2013; Roth et al., 2005). Thus, future research should also examine group differences on a self-report measure of executive function, such as the Behavior Rating Inventory of Executive Function—Adult version (Roth et al., 2005) that asks participants about their problems functioning in real-life situations. This scale includes nine separate subscales, including the three that assess cognitive flexibility, inhibitory control, and working memory.

Summary and Conclusion

In this study, traditional yoga practitioners, restorative yoga practitioners, and no-yoga control participants did not significantly differ on tasks of executive function. These results are inconsistent with past research examining the acute effects of individual yoga sessions and lengthier yoga interventions that resulted in improvements in cognitive flexibility, inhibitory control, and working memory updating. However, the lack of significant group differences in the current study may be a result of disrupted yoga practice due to the COVID-19 pandemic. Future research should account for the recency and consistency of yoga practice to determine if the effects on executive function, assessed with both performance-based and self-report measures, depend upon constant practice.

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