ASSOCIATIONS BETWEEN MUSICAL EXPERIENCE AND SELF-REGULATION:

COGNITIVE, EMOTIONAL, AND PHYSIOLOGICAL PERSPECTIVES

AN ABSTRACT

SUBMITTED ON THE FIFTH DAY OF MAY 2021

TO THE DEPARTMENT OF PSYCHOLOGY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

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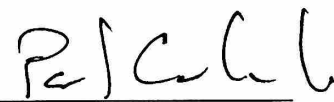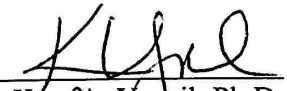
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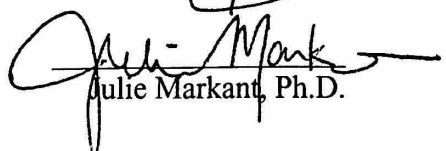
FOR THE DEGREE

OF

DOCTOR OF PHILOSOPHY

BY

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JENNA WINSTON

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Abstract

Musical experience is associated with a host of benefits to self-regulatory processes across multiple psychological domains. The purpose of the studies presented in this dissertation was to examine relationships between musical experience and cognitive, emotional, and physiological self-regulation. Cognitive regulation was measured with tasks of executive functions; emotional regulation was measured by self-efficacy, incidences of mental illness, depressive symptoms, and perceived chronic stress; and physiological regulation was measured by cortisol levels in response to an acute psychological stressor. Findings on cognitive regulation showed that enrollment in music programming during childhood was associated with enhanced working memory maintenance and updating, and musical experience in early adulthood was associated with enhanced cognitive flexibility. Among musically experienced adults, the ability to create a four-part harmonization was also associated with enhanced cognitive flexibility. With respect to emotional regulation, continued enrollment in music programming was associated with higher regulatory self-efficacy in children, and musically trained adults demonstrated lower incidences of mental illness, depressive symptoms, and perceived chronic stress. No physiological differences were found in acute cortisol reactivity between musicians and non-musicians, despite lower levels of perceived chronic stress in musicians. Taken together, these results suggest that cognitive and emotional self-regulation are impacted by music training, but not physiological regulation. However,

divergent findings may depend on the type of musical experience measured, and the age of musical engagement.

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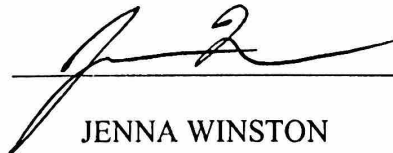
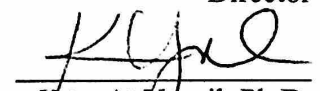OF TULANE UNIVERSITY

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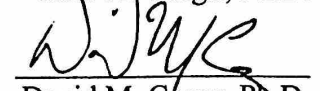
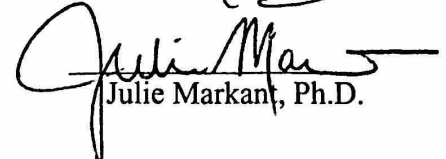DOCTOR OF PHILOSOPHY

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Chapter I: General Introduction

Self-regulation is broadly defined as the internal processes used to make adaptive adjustments to one's mental and physiological states (Eisenberg & Zhou, 2000; Eisenberg et al., 2007; Liew, 2011). Self-regulation can be understood in terms of cognitive, emotional, or physiological regulation, or as a model encompassing multiple domains. While it can be measured in a variety of ways, self-regulation in some form is negatively related to several types of psychopathology, and predicts developmental outcomes in children such as social and intellectual milestones, academic achievement and physical health (see Nigg et al., 2017 for a review of various types of self-regulation and their associated outcomes). Given the importance of different aspects of self-regulation to physical and mental health, an ongoing area of interest is the study of interventions that seek to improve self-regulation.

For nearly three decades, psychologists have investigated the benefits of musical experience to cognitive, emotional, and physiological dimensions of self-regulation. The current work will examine relations between executive functions, self-efficacy, and physiological stress reactivity as they relate to musical experience in childhood and adulthood. Understanding such relations will offer a more comprehensive view of how musical experience can lead to greater self-regulation across cognitive, emotional, and physiological systems.

But why should scientists study music? Music training is fun and engaging with an emphasis on skill-building, often accompanied by a strong social component. Music-based interventions may be less vulnerable to problems with attrition than classic behavioral or pharmaceutical interventions, and may be met with more intrinsic motivation due to the added benefit of learning a new skill and/or bonding with a new group of people. In addition, unlike pharmacological interventions, musical experience is completely non-invasive and has no risk of side-effects; the risk of engaging in music training is simply that one does not enjoy it. Music-based interventions may also alleviate some of the stigma associated with interventions for special populations, particularly in school-aged children. As a preventative measure, implementing music-based interventions in schools may address more holistic root causes of certain issues, rather than respond to individual problems related as they emerge. In addition to attenuating stigma from others, this could also lead to less negative beliefs about the self that can result from requiring more attention than one's peers. Overall, music as an intervention is not only effective, but has the power to shift attention from treating illness to promoting wellness. Therefore, further understanding of *how* music brings about beneficial outcomes is a worthy area of study, because it can aid in the development of effective interventions.

1.1. Executive Functions

One area in which authors have studied music-related benefits is executive functions. Executive functions, also referred to as executive control or cognitive control, refer to a set of top-down cognitive processes that allow one to regulate thoughts and

behavior (Diamond, 2013; Miyake & Friedman, 2012; Miller & Cohen, 2001). The use of executive functions is effortful, requires attentional resources and control, and is necessary for a wide range of daily activities that require regulation of thoughts and behavior (Miyake & Friedman, 2012).

Perhaps because they are so important in our daily lives, these abilities are associated with several predictors of long-term achievement and well-being. For example, executive functions are reportedly more predictive of academic readiness than intelligence (Blair & Razza, 2007). In addition, they can predict reading and math abilities (Gathercole et al., 2004) and academic achievement (Best et al., 2011) at all grade levels. In adults, higher performance on measures of executive functions are associated with higher job success (Bailey, 2007), marital satisfaction (Eakin, et al., 2004), and overall quality of life (Brown & Landgraf, 2010; Davis et al., 2010). Poor executive functions are associated with increased risk of obesity, substance abuse, and overeating (Crescioni et al., 2011; Miller et al., 2011; Riggs et al., 2010), as well as social problems such as crime, violence, and emotional dysregulation (Broidy et al., 2003; Denson et al., 2011).

Clearly there is much to be gained from improved executive functions. It is therefore important to understand how and why certain experiences and interventions may be beneficial. In this chapter, evidence of a relationship between musical experience and improved executive functions will be evaluated. However, before they can be discussed in relation to musical experience, executive functions must be defined for the current discussion.

1.2. Defining Executive Functions

Despite an extensive body of work on the subject, the term "executive functions" is defined differently in different contexts, and definitions from different sources are not always consistent (see Jurado & Rosselli, 2007). Therefore, in order to define the term for the current studies, different theories and definitions will be evaluated. The term "executive" originated from Baddeley and Hitch's (1974) account of a singular central executive component to working memory, responsible for the voluntary control and regulation of cognition. The term "executive functions" was first used by Lezak (1982), and expanded Baddeley's account of the central executive by describing it as a separable group of functions, rather than one unified construct. These diverging viewpoints gave way to one of the central debates in executive functions research: do they reflect a single, underlying ability, or separable cognitive processes?

In an attempt to address this question, Miyake and Friedman (2000) performed a latent variable analysis in which they measured scores on a range of commonly used executive function tasks, and analyzed how scores on each task loaded on three latent constructs. They found that nine tasks loaded onto three separable factors: shifting, inhibition, and updating. Despite such evidence for separability, the authors found that factor scores for these three components were all moderately correlated with one another. They described their findings as demonstrating both "unity" and "diversity," where the overall construct can be understood in terms of separable, but highly related, functions. Other researchers have sought to identity an underlying ability or factor that accounts for the relatedness among separable functions. Strong relationships have been demonstrated between overall performance on groups of executive function tasks and abilities such as

reasoning and processing speed (Salthouse, 1996; 2005), inhibition (Moreno & Farzan, 2015; Miyake & Friedman, 2000), and fluid intelligence (Duncan et al., 1995; 1996; Salthouse et al., 2003; 2006). However, the nature of a single construct that underlies all executive functions remains unknown.

Even so, these findings formed the basis of the most pervasive definition of executive functions used today. This definition, referred to here as the three-component model, describes executive functions as comprised of inhibition, working memory, and cognitive flexibility (Diamond, 2013; Miyake & Friedman, 2000). Inhibition, sometimes referred to as inhibitory control, is defined as having control over attention, behavior, thoughts, and/or emotions, in a way that overrides an existing habit or internal motivation (Diamond, 2013; Moreno & Farzan, 2015; Miyake & Friedman, 2000). Working memory, sometimes referred to as updating, refers to one's ability to hold and manipulate a limited amount of mental information for a limited duration (Baddeley & Hitch, 1974). Cognitive flexibility, sometimes referred to as shifting or switching, refers to readily being able to adjust to new or changing task demands, such as priorities, rules, or obstacles (Diamond, 2013). According to this view, these three core executive functions build on one another to create higher-order executive functions, such as problem-solving or planning (Lunt et al., 2012).

Other views of executive functions center more on problem-solving than on identifying individual functions. Phillip Zelazo and colleagues (1997) have rejected the notion of a singular construct, or "central executive." Their approach to studying executive functions was influenced by the idea of interactive functional systems, first posited by Luria (1973). In this view, executive function represents a macro-level

construct underscored by subfunctions that are integrated to achieve one common goal:

problem-solving (Zelazo, et al., 1997). The authors of this view describe problem-

solving in terms of four distinct phases: representation, planning, execution, and

evaluation. It is argued that different subfunctions are needed within each of these four

phases, and that their integration is necessary to understand problem-solving in a single

framework (Zelazo, et al., 1997). Zelazo has also incorporated issues concerning

emotional regulation into executive functions discourse, identifying "hot" executive

functions, which involve effortful emotional regulation, and "cool" executive functions,

which rely more strictly on cognitive control (Zelazo & Carlson, 2012).

In another well-known model, Stuss and Alexander (2007) shaped their view of

executive functions based on fidelity to separable brain processes. They, too, identified

three components associated with executive functions. However, rather than focusing on

inhibitory control, working memory, and cognitive flexibility, they sought to differentiate

distinct frontal lobe processes through studying focal frontal lobe lesions (Stuss et al.,

1995). They identified brain-behavior mapping for these processes, which included (1)

energization - the process of initiating a response, (2) task setting – the process of

connecting a stimulus to a response, and (3) monitoring – adjusting to the task over time.

Through reviewing studies of focal frontal damage, they proposed that the superior

medial, left lateral, and right lateral frontal lobes house each of the three processes,

respectively (Stuss & Alexander, 2007).

A strength of Stuss and Alexander's argument is that it was developed with

fidelity to the brain. Just as the definition of executive functions is elusive, so is our

understanding of their distribution in the brain. Typically in neuroimaging studies of

executive functions and functional brain activation, executive functions are measured using a single task, rather than a representative battery. In an effort to synthesize results across such studies, Niendam and colleagues (2012) performed a meta-analysis of nearly 200 functional neuroimaging studies, including data from over 2,800 participants. Their results demonstrate support for Miyake and Friedman's (2000) view of executive functions that suggests unity *and* diversity among the processes involved. Across studies, a common cognitive control network including the prefrontal, dorsal anterior cingulate, and parietal cortices was activated for all measures of executive functions (Niendam et al., 2012). These findings support the "unity" of executive functions described in Miyake and Friedman's (2000) approach.

However, neuroimaging studies also provide evidence for diversity of executive functions within the cognitive control network. In line with previous accounts of the functional connectivity in the prefrontal cortex and its role in higher order cognition (Miller & Cohen, 2001), this fronto-cingulate-parietal network is distributed in the brain, and the functional contributions of each structure vary depending on which executive functions are being engaged (Niendam et al., 2012). Frontoparietal connections have been shown to be more heavily represented during planning and dual task coordination, which map onto the cognitive flexibility component of executive functions (Spreng et al., 2010; Vincent et al., 2008). The prefrontal cortex may play a larger role in forming task-specific representations and maintenance, which reflects abilities involved in working memory (Dosenbach et al., 2006; Yarkoni et al., 2009). The dorsolateral prefrontal cortex has also been associated with response selection and inhibition, suggesting a role in inhibitory control (Asaad et al., 2000; Bellebaum & Daum, 2007; Watanabe, 1990,

1992). The anterior cingulate cortex and the parietal lobes are thought to play supportive roles for the dorsolateral prefontal cortex; the anterior cingulate detects conditions and conflicts and then engages the dorsolateral prefrontal cortex for cognitive control processes (Egner & Hirsch, 2005; Kerns et al., 2004; MacDonald et al., 2000), while parietal activation provides the dorsolateral prefrontal cortex with information on stimulus salience and learned stimulus-response pairings (Bunge, Hazeltine, Scanlon, Rosen, & Gabrieli, 2002; Bunge et al., 2003; Miller & Cohen, 2001; Posner & Petersen, 1990). So, despite a unified network of functional activity, separable parts of the network support Miyake and Friedman's (2000) claim for diversity across functions as well.

After considering the evidence for different approaches to executive functions, the current work will adhere to the three component model to define executive functions (Miyake & Friedman, 2000). One strength of this model is that it is supported by neuroimaging research on a separate, but unified network of cognitive control, where each of the three core components have separable but related neural correlates within a frontal-parietal-cingulate network. Another strength of this model is that it was developed with consideration of the task impurity problem. This refers to the notion that tasks of executive function must probe other aspects of cognition in order to be completed. For instance, performance on a task that requires selection of a verbal or visual response will be impacted by speed of articulation or visual processing (Snyder et al., 2015). Even further, tasks that are designed to test one executive function may enlist non-target executive functions to varying degrees (Diamond, 2013). In developing the three-component model, Miyake and Friedman (2000) took this into account by creating factors for each core component, made up of scores on multiple measures. Furthermore,

the three-component model does not rely on generalized measures of executive functions. Rather, it highlights the need for separability in measurement by using comprehensive test batteries rather than single representative tasks. Finally, as will be discussed in Chapter II, the developmental trajectory of executive functions is also consistent with the three-component model.

1.3. Executive Functions and Musical Experience

Evidence for a positive relationship between musical experience and executive functions has become clearer in recent years. Some authors have suggested that executive functions serve as a mechanism of transfer from musical experience to non-musical outcomes (e.g. Moreno & Farzan, 2015). However, despite ample evidence for a positive association between musical experience and executive functions, more findings have led to more questions about the nature of the relationship. What types of experience influence which executive functions? At what age are we most susceptible to experience-dependent changes in executive functions? Are certain executive functions more or less likely to change with musical experience? The answers to these questions remain unknown. In order to move towards answering them, which functions are studied, how/when they are measured, and different experimental designs all must be considered.

Several investigations provide evidence that music training is positively related to working memory. Longitudinal studies of working memory and music training have mainly been conducted on children. Recently, Guo and colleagues (2018) compared the effects of a six week keyboard training intervention for young children to an untrained control group. While they measured multiple executive functions, they found significant

post-training improvement only on the backwards digit span, a measure of working memory. Dege et al (2017) reported a musician advantage for working memory in musically trained children, which has also been reported in several cross-sectional studies on adults (as follows). A study of executive functions in adult musicians and non-musicians revealed a musician advantage on the backwards digit span task (Zuk et al., 2014). This finding was replicated by Clayton et al (2016) in a comparison of adult musicians and non-musicians on an executive function test battery. Pallesen (2010) demonstrated an adult musician advantage on a related measure of working memory; the musical variation of the n-back test. Furthermore, Slevc and colleagues (2016) showed that musicians outperformed non-musicians on auditory and visual updating tasks. Taken together, these findings indicate that music training enhances working memory in children and adults.

There is also substantial evidence for a music-dependent advantage in inhibitory control. As with working memory, longitudinal studies of inhibitory control have been primarily conducted with children. Moreno et al., (2011) measured performance on the go/no-go test of inhibitory control before and after a music training intervention in young children. Children who participated in the music intervention demonstrated higher accuracy on the task than control children, and an increased P2 event-related potential for no-go stimuli. The authors hypothesized that, given adult studies that show a relationship between inhibitory control and music training, the observed electrophysiological change may precede behavioral advantages (Moreno, et al., 2011). Indeed, cross-sectional work by the same group has shown a musician advantage for the go/no-go task in adults (Moreno, et al 2014; Moreno & Farzan, 2015). Other well-known paradigms used to

study inhibitory control include the Simon task and the Stroop task, both of which are associated with a musician advantage in adults (Stroop: Stewart et al., 2013; Travis et al., 2011; Amer, et al., 2013 / Simon: Bialystock & Depape, 2009; Slevc et al., 2016; Schroeder et al., 2016) and children (Stroop: Grégoire et al., 2015; Sachs et al., 2017 / Simon: Joret, et al., 2017). While these results indicate a strong relationship between inhibitory control and music training, there are still divergent findings that show no effects of musicianship on performance in these same tasks (Zuk et al., 2014; Vasuki, et al., 2017). Recent evidence suggests that divergent findings may be related to the type or class of instrument played by musicians in the experimental groups. Slater et al. (2017a, 2017b), reported enhanced inhibitory control in percussionists in comparisons with vocalists and non-musicians, suggesting that effects of musical experience on executive function may be specific to practices among those studying particular classes of instruments or music genres. These findings suggest that music training enhances inhibitory control in adults and children, and that certain elements of music training may selectively effect inhibitory control more than others.

Finally, the third component, cognitive flexibility, is also positively related to musical experience. Zuk et al (2014) showed that cognitive flexibility was enhanced in both children and adults. Both musically trained children and adults showed an enhancement in verbal fluency, and adult subjects also showed an enhancement in design fluency. Moradzadeh and colleagues (2014) also reported enhanced cognitive flexibility in musically trained adults, where musicians demonstrated a lower cost of task switching and dual-task coordination on performance in a dual-task coordination paradigm. Music-dependent advantages have also been shown in the Trail-Making Test, a measure of set-

shifting, in older adults (Bugos et al., 2007) and children (Saarikivi et al., 2016; Saarikivi et al., 2019). However, compared with working memory and inhibitory control, fewer studies include tasks of cognitive flexibility. Therefore, less is known regarding the relationship between cognitive flexibility and musical experience when compared to working memory or inhibitory control.

1.4.The Current Studies

The aim of the current studies was to investigate differences between musicians and non-musicians in cognitive, emotional, and physiological measures of self-regulation. The primary focus is on cognitive self-regulation, measured with executive functions. Chapter II examined executive functions in musically trained school-aged children, and tested the hypothesis that childhood music training can improve executive functions.   In Chapter III, executive functions in adults with high levels of musical training and specialized knowledge of composition were investigated. The study tested the hypothesis that musicians with high composition abilities will perform better on measures of executive functions than musicians with an equal amount of musical experience, but lower compositional skill.   Emotional self-regulation was measured with self-efficacy, perceived chronic stress, and depressive symptoms. In Chapter II, findings on various domains of self-efficacy, an emotional indicator of how well one believes that can regulate their own thoughts and behavior, are reported in musically trained children. It was hypothesized that musically trained children would demonstrate enhanced general self-efficacy. In Chapter IV, perceived chronic stress and depressive symptoms were compared in musically trained and untrained adults. It was hypothesized that musicians

would show more psychological distress than non-musicians. Physiological regulation was measured with cortisol reactivity to and recovery from an acute psychological stressor. The study described in Chapter IV tested the hypothesis that musically experienced adults will show lower cortisol reactivity and quicker recovery than non-musicians during an acute psychological stressor. Collectively, these studies provide novel insights into music-dependent enhancements in self-regulatory abilities and their implications for physical and mental well-being. These insights can inform future research the development of music-based interventions across these areas. Such interventions can utilize a single treatment to address a broad host of outcomes, which has the potential to improve people's lives across ages and ailments.

Chapter II: Effects Of Music Programming In School-Aged Children

2.1 Introduction

Previous reports indicate that musical experience is associated with enhanced executive functions. Given this well-documented relationship, music training may serve as a useful executive function intervention. One population that may be especially well-suited for a non-invasive, cost-effective executive function intervention is children living in poverty. Early childhood stressors associated with poverty are detrimental to the healthy development of executive functions. Not only is lower socioeconomic status associated with poorer executive functions in childhood, but the amount of time spent in childhood poverty also negatively predicts cognitive abilities in adulthood (Evans & Schamberg, 2009). These enduring, negative effects can take hold even in the first year of life (Blair et al., 2011), and are associated with decreased gray matter volume in frontal areas responsible for executive functions (Hair et al., 2015). Previous studies have shown that children with lower cognitive abilities show the most improvement in interventions aimed at improving executive functions (Diamond & Lee, 2011). Music training may therefore be especially useful to children prone to executive dysfunction as a preventative or therapeutic buffer.

It is important to focus on risk factors of executive dysfunction in children because executive functions develop during childhood. Whereas Miyake et al. (2000) demonstrated three separable components of executive functions in adults, investigations

of child populations suggest that executive functions emerge as a single construct, and differentiate over time between early childhood and adolescence. For instance, in a cross-sectional study comparing executive functions in different age groups, Shing et al. (2010) found memory maintenance and inhibition to be undifferentiated until approximately ten years of age (Shing et al., 2010). Yet, evidence for the three-factor structure has been reported for children ages seven to fourteen (Wu et al., 2011), eight to thirteen (Lehto et al., 2003), eleven (Rose et al., 2011), and fifteen (Lee et al., 2013). Consistent with these findings, other factor analyses suggest that executive functions are attributable to a single factor in three-year-olds (Willoughby et al., 2011; Wiebe et al., 2011; Fuhs & Day, 2011), four- and five-year-olds (Willoughby et al., 2012), and six-year-olds (Hughes et al, 2010). So, while the exact age of differentiation remains unknown, previous findings do converge on the fact that they separate in the school-aged years. This suggests that the school-aged window may be an ideal developmental time to administer music-based interventions to improve executive functions.

Chapter I provided evidence for musical training improving executive functions in adults, demonstrating that music training may be used as a valuable intervention for preventing executive dysfunction or improving existing functions. But can the same be said for children? Several studies have compared musically trained and untrained children. Longitudinal studies have provided evidence for music-dependent enhancements of working memory in 6-8 (Guo et al., 2018) and 8-10 (Dege et al., 2017) year old children. Furthermore, advantages in inhibitory control have been observed in musically trained school-aged children on the go/no-go task (Moreno et al., 2011), Stroop task (Gregoire et al., 2015; Sachs et al., 2017), and Simon task (Joret, et al., 2017). Zuk

and colleagues (2014) demonstrated that musically trained children performed better on a measure of task switching than untrained children, indicating an advantage in cognitive flexibility as well. While there is substantial evidence for musical training leading to benefits in executive functions for school-aged children, many authors do not report the socioeconomic status of their participants. Music lessons tend to be expensive and time-consuming, and therefore often reserved only for those of higher socioeconomic status. Given the observed differences in executive functions between children from low income households and those who are not (Blair et al., 2011; Evans & Schamberg, 2009), it is important to consider whether these results generalize to children living in poverty.

A few authors have conducted longitudinal studies tracking related outcomes of children from low income households enrolled in tuition-free music programming. Such efforts have demonstrated that music training leads to enhanced neurodevelopment of auditory processing, as indicated by electrophysiological (Habibi et al., 2016; Kraus et al., 2014) and structural (Habibi et al., 2018) markers. For instance, Kraus and colleagues demonstrated that two years of music enrichment in impoverished youth led to an enhanced auditory brainstem response to speech sounds (Kraus et al., 2014), which has been linked to reading abilities (Hornickel et al., 2009; White-Schwoch & Kraus, 2013), and selective attention (Strait et al., 2015). While these findings demonstrate that music training has the potential to alter neural, and by extension, cognitive development in low income children, they do not directly address executive functions. Since children from low income families are more likely to suffer from executive dysfunction (Blair et al., 2011; Evans & Schamberg, 2009), executive functions differentiate during the school-aged years, and childhood music training can enhance executive functions, there

is an urgent need for work testing the relationship between executive functions and music training in children from low income households.

Given that music programming leads to enhanced cognition, one question that arises is, how? One psychological construct that is thought to buffer the relationship between educational disadvantages and cognition is self-efficacy (Zahodne et al., 2015). Self-efficacy is broadly defined as "the belief that one can achieve what one sets out to do." (Bandura, 1982). Self-efficacy can be measured in terms of a specific domain (ie: academic self-efficacy, social self-efficacy) or as a general belief about the self across domains. According to Bandura's social cognitive theory, self-efficacy plays a central role in self-regulation of motivation, due to the effects that people's expectations have on their willingness to undertake challenges, expend effort, and persevere in the face of obstacles or failure (Bandura et al., 2001). Furthermore, higher self-efficacy can also lead to greater self-regulation of emotional states, which affects vulnerability to stress and depression (Bandura, 2012). Self-efficacy also impacts important decisions, since people tend to select activities and challenges that they feel confident in, and avoid those that they do not (Schunk & Pajares, 2002). It has also been reported to increase the likelihood of social engagement and physical health in older adults (Perkins et al., 2008).

Self-efficacy is also related to executive functions and socioeconomic status. One study showed adults with higher education levels, which were indicative of socioeconomic status, demonstrated higher self-efficacy (Zahodne et al., 2015). Furthermore, self-efficacy was associated with higher performance on multiple tasks of executive functions, and associations between self-efficacy and executive functions were highest for individuals with lower education levels (Zahodne et al., 2015). Thus, efforts

to enhance self-efficacy in its own right, as well as in relation to executive functions, are important for offsetting developmental disadvantages that may be incurred by children living in poverty.

Several behavioral interventions have been shown to improve self-efficacy, such as exercise (Fillipas et al., 2006), nutritional education (Poddar et al., 2010), and peer mentoring (Jones et al., 2019). However, there are relatively few studies on the effect of musical experience on general self-efficacy. Several studies have focused on *musical* self-efficacy, which refers to self-efficacy specifically for musical ability (McPherson & McCormick, 2006; Ritchie & Williamon, 2012; Martin, 2012; Miksza, 2015; Hewitt, 2015; Hartz & Bauer, 2016; Bugos et al., 2019; Zarza-Alzugaray et al., 2020). Others have focused on general self-efficacy as a predictor of music performance anxiety, a form of social anxiety experienced by musicians before, during, and after performing (Orejudo et al., 2017; Sarikaya & Kurtaslan, 2018; Gonzalez et al., 2018; Macafee & Gilles, 2020). However, the impact of music training on other forms of self-efficacy is less clear. One study revealed that children involved in musical activities reported higher general self-efficacy than those who were not (Ritchie & Williamon, 2011), whereas in a study on older adults, a short-term music intervention improved musical self-efficacy, but not general self-efficacy (Bugos et al., 2016). In another investigation of older adults, engagement in a community orchestra was associated with enhanced musical self-efficacy but not general self-efficacy, and general self-efficacy and musical self-efficacy were positively associated in these individuals (MacRitchie & Garrido, 2019). From these limited findings, it may be the case that children's general self-efficacy is more mutable than older adults', and therefore more likely to respond to an intervention.

While previous studies suggest that general self-efficacy may be related to musical experience in children, it is unclear how and when these relations are formed. Further study of this issue is important due to the wide-reaching implications of enhancing general self-efficacy on overall well-being and self-regulation.

Thus far, support for a positive relationship between musical training, self-efficacy, and executive functions have been discussed. Furthermore, evidence has been presented that suggests that children living in poverty stand to gain the most from a music-based intervention aimed at improving executive functions and self-efficacy. The current study aimed to test this relationship in impoverished youth in New Orleans. In 2017, New Orleans reported the highest poverty rate among the 50 largest metro areas in the United States, with 18.6% of its residents living below the poverty line (labudget.org). However, in tandem with its high poverty rates, the importance of music in New Orleans' culture is unparalleled. Walking down the street on any given day, one might encounter a brass band, a secondline parade, a jazz trio set up on the street, or a Mardi Gras Indian celebration. Thus, New Orleans is the ideal city to study how music training may impact development in impoverished youth, and it is where such interventions are most needed and culturally relevant. The Roots of Music is a tuition-free music-based mentoring program for middle-school-aged children based in New Orleans. In order to be eligible for enrollment, students must qualify for free or reduced rate school lunch, which is an indicator that their household lives below the state poverty line. Students receive training in music theory and their primary instruments five days per week, 12 months out of the year. They are trained to participate in a New Orleans style marching band that performs all over the city, including but not limited to Mardi

Gras parades, New Orleans Jazzfest, and private events like weddings and corporate parties. The Roots of Music also provides international travel opportunities for their students to perform at jazz festivals around the world, most recently including Brazil and France. All of their music programming, roundtrip transportation to class, meals, instruments, performance attire, and travel are completely free to the students and their families.

The current study tested relationships between musical experience and cognitive self-regulation, measured by executive functions, and emotional self-regulation, measured across multiple domains of self-efficacy, in students of The Roots of Music. Multiple executive functions were measured using a representative test battery, and self-efficacy was measured with a questionnaire that probed academic, social, and self-regulatory domains. Results are from the first year of an ongoing longitudinal study, and these preliminary findings were reported cross-sectionally. Children were grouped according to how long they have been enrolled in the program, and executive function and self-efficacy scores were compared between these groups. It was hypothesized that scores on executive function tasks and our self-efficacy questionnaire would be higher in children who have been enrolled in the program longer.

2.2 Methods

Participants

46 9-13 year-old children were recruited from The Roots of Music, with a mean age of 11.44. 16 children were new to the program, 15 children had been in the program for one to two years, and 15 children had been in the program for two or more years at the time

of testing. The majority of participants were male (40 males, 6 females), and all

participants identified as Black/African American. All participants qualified for the

National School Lunch and Breakfast programs, which assesses eligibility based on

household income.

Assessment of Executive Functions

All participants completed a battery of cognitive tests commonly used to measure

executive functions including the Trail-Making Test Parts A and B, Berg Card Sort, Corsi

Blocks, and Tower of Hanoi. These tests were chosen in order to provide a

representative test battery that assesses as many components as possible, while remaining

appropriate for children. The tasks were administered on portable tablets and accessed

through the Psychology Experiment Building Language (PEBL) software. A description

of each task and the subcomponent(s) that it probes follows:

(a) Trail-Making Test (Parts A and B)

The trail making test measures processing speed and task switching, the

latter of which is a measure of cognitive flexibility (Reitan, 1958; Lezak, 1995). In Part

A of the task, participants were instructed to connect 25 consecutive dots containing

either numbers or letters. In either condition, the letters or numbers were presented

consecutively, such that numbers 1-25 or letters A-Y were included in a given trial.

Participants were told to connect the dots alphabetically in the letter condition (A-B-C-

D…), and numerically in the number condition (1-2-3-4…). In Part B of the task,

participants were presented with 25 dots containing both letters and numbers. In this

condition, participants were instructed to connect the dots in numerical and alphabetical

order, alternating from number to letter to number to letter (1-A-2-B…). Median reaction times to each dot in Part A were used as a dependent measure for processing speed, and median reaction times in Part B were used a dependent measure for task switching.

(b) Berg Card Sort

The Berg Card Sort is a computerized version of the Wisconsin Card Sort, named for one of the original authors of the task, Esta Berg (Berg, 1948). The card sort task measures set-shifting, which is a measure of cognitive flexibility. In this task, participants are presented with four virtual cards, each containing a different shape, number of shapes, and color of shapes. Participants were then presented with a new card, and told to sort the new card into the correct pile, but not how to sort (by color, shape, or number). Participants received feedback each time they sorted a new card. After ten correct trials, the "rule" for sorting would change, and a previously successful sorting strategy would no longer elicit positive feedback. Since participants needed to achieve ten correct sorts to move on to a new sorting rule, the number of rules reached was used as a dependent measure. The number of perseverative errors was also included as a dependent measure.

(c) Tower of Hanoi

The Tower of Hanoi task assesses problem-solving and planning abilities (Kotovsky et al., 1985). Participants were presented with two sets of three discs, one set was the "goal state," and one set was the workspace. Participants were instructed to move the discs in the workspace into the configuration shown in the goal state. Participants were not limited in the amount of moves they could use to get the discs into

the goal state. The task included 10 trials, with different goal state configurations for each one. The dependent measure was the total number of moves used to complete ten problems.

(d) Corsi Blocks

The Corsi Blocks task is a measure of visuospatial short-term memory (Kessels et al., 2000). Participants were presented with a grid of squares on a screen, and two squares lit up sequentially. Participants were asked to click on the square in the order that they lit up. If they answered correctly, the next trial would show three squares lighting up, and so on, until they answered two consecutive trials incorrectly. The dependent measure was memory span, indicated by the highest number of squares that participants were able to recall.

Assessment of Self-Efficacy

General self-efficacy was measured using a 21-item scale. The scale was constructed according to Bandura's guide for constructing self-efficacy scales (Bandura, 2006). In the guide, Bandura provides several sample items that assess self-efficacy across various domains in children. This assessment included the provided survey items meant to assess academic, self-regulatory, and social efficacy. Instructions and scoring for the assessment were also adapted from Bandura's scale construction guide. Responses were measured on a 10-item Likert scale from 0-100, arranged in increments of 10.

Procedure

Study protocols were approved by the Tulane University Institutional Review Board. Informed consent was obtained in writing from parents/guardians before any child was approached about participating in the study. Once parental consent was obtained, children were approached at The Roots of Music. Before any study procedures were initiated, children provided written assent. Both guardians and children could end their participation in the study at any time. All children were tested individually in an isolated room on site at The Roots of Music. All testing sessions began with the self-efficacy questionnaire and a second questionnaire probing past musical experience and demographic variables. All six executive function tasks were completed in a row, in a counterbalanced order across participants. These testing sessions were part of an ongoing longitudinal study, and some children were measured more than once. For children measured more than once, only their first testing session was included in the current analysis.

Statistical Analysis

Scores greater than three standard deviations from the group mean were considered outliers and removed for all self-efficacy and executive function measures before analysis. Data were analyzed using Analysis of Covariance (ANCOVA), where outcome scores were included as dependent variables, and years in program (less than 1, 1-2, 2+) was included as a fixed factor. In order to control for any developmental differences between the groups, age (at time of testing) was included as a covariate in each analysis. P-values for each ANCOVA were adjusted for multiple comparisons using the Holm

adjustment (Holm, 1979). For significant results, Bonferroni *aposteriori* comparisons were performed on main effects of marginal means across the levels of years in program.

2.3. Results

Demographics. Sex of participants did not significantly differ between the groups ($X^2(1$, $N=46)=1.292$, $p=.524$). Age of participants at the time of testing was significantly different between groups ($F(2,44)=5.952$, $p=.005$), such that those in the program for less than one year ($M=11.06$, $SD=.307$) and between one and two years ($M=10.93$, $SD=.328$) were younger than those in the program for two or more years ($M=12.33$, $SD=.317$). In order to control for the difference in age between groups, Age was included as a covariate in all subsequent analyses.

Self-Efficacy. After adjusting for multiple comparisons, there was a significant main effect of years in program for regulatory self-efficacy ($F(2, 36)=6.890$, $p=.012$, $\eta_p^2=.301$), but not for academic ($F(2, 36)=.470$, $p=.837$, $\eta_p^2=.029$), social ($F(2, 36)=2.212$, $p=.252$, $\eta_p^2=.121$), or general ($F(2, 36)=4.441$, $p=.06$, $\eta_p^2=.217$) self-efficacy. Bonferroni *aposteriori* comparisons revealed a significant increase in regulatory self-efficacy scores from less than one year to 1-2 years of programming ($p=.004$), but not 2+ years ($p=.087$). Figure 1 summarizes results across each domain self-efficacy.
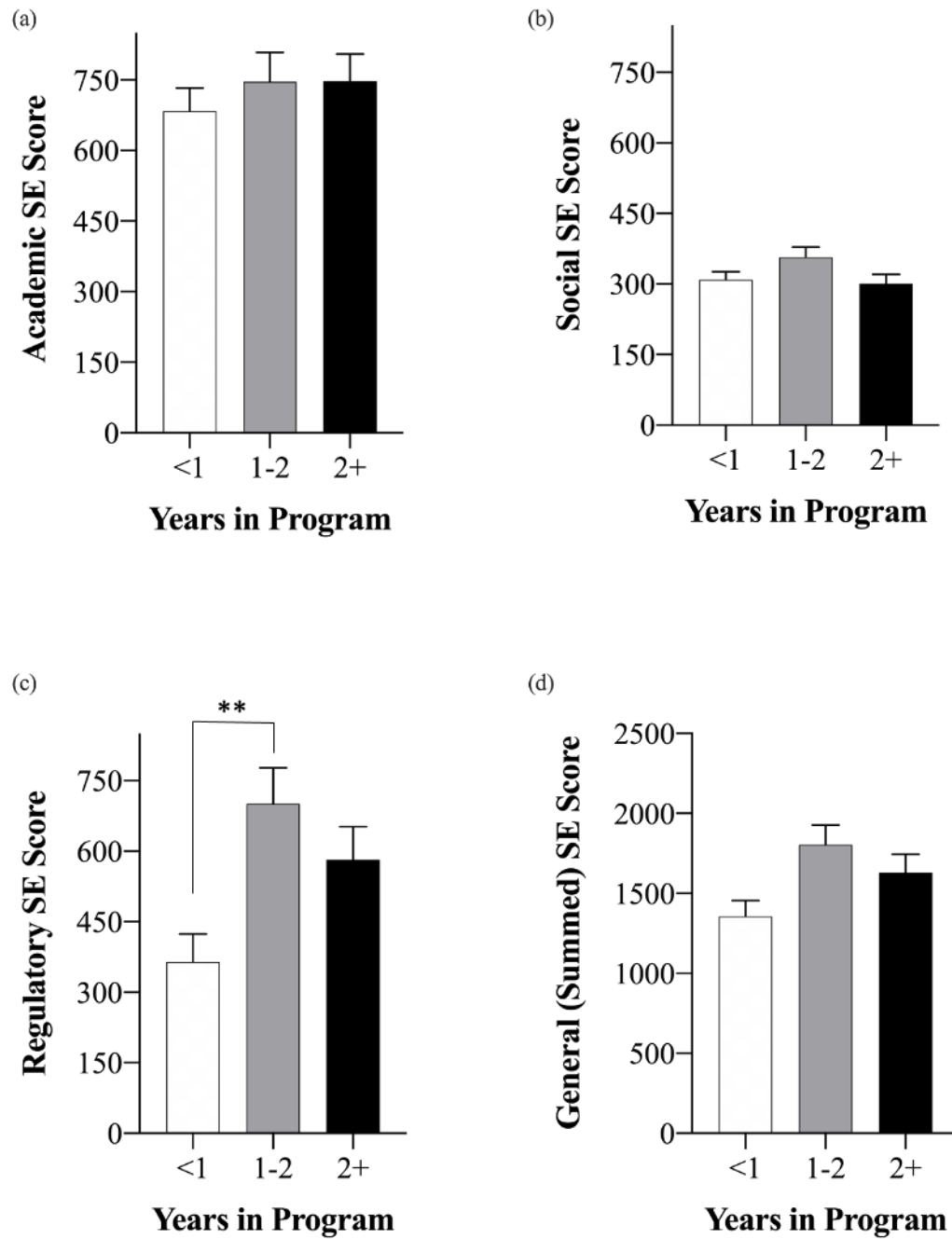
**p<.01

Figure 1. Self-efficacy (SE) scores across academic (a), social (b), regulatory (c), and general (d) domains.

Card Sort. There was a significant main effect of years in program on the number of categories achieved ($F(2, 39)=6.635$, $p=.028$, $\eta_p^2=.269$), but not perseverative errors ($F(2, 39)=.702$, $p=.999$, $\eta_p^2=.039$) in the card sort task, see Figure 2a. Bonferroni *aposteriori* comparisons revealed a significant increase in number of categories achieved between those with less than one year and 2+ years of programming ($p=.003$), and no significant difference between those with less than one year and 1-2 years ($p=.263$), or 1-2 years and 2+ years ($p=.334$) of programming. See Figure 2b.
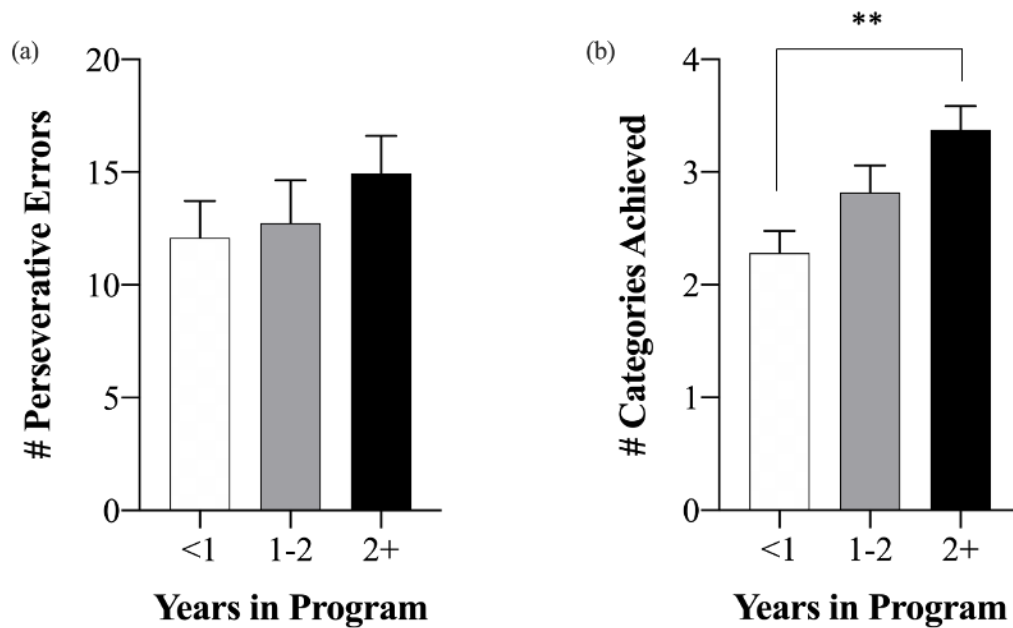
**p<.01

Figure 2. Total number of perseverative errors (a) and number of categories achieved (b) on the Card Sort.

Corsi. There was no significant effect of years in program on Corsi score ($F(2, 37)=2.101$, $p=.69$, $\eta_p^2=.113$), see Figure 3.
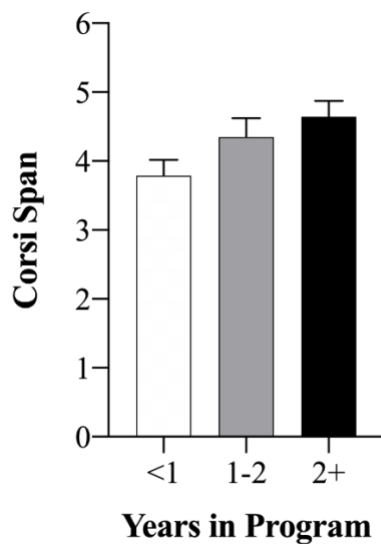
Figure 3. Corsi Blocks span.

Trail-Making Test (TMT): Parts A and B. For TMT-A, there were no significant effects of years in program on median reaction times for the numbers ($F(2, 34)=1.009$, $p=.999$, $\eta_p^2=.063$) or letters ($F(2, 34)=2.460$, $p=.618$, $\eta_p^2=.141$) conditions, see Figure 4a and 4b. For TMT-B, there was no significant effect of years in program on median reaction times

for the mixed (number, letter, number, letter) condition ($F(2, 34)=1.399$, $p=.999$, $\eta_p^2=.083$), see Figure 4c.
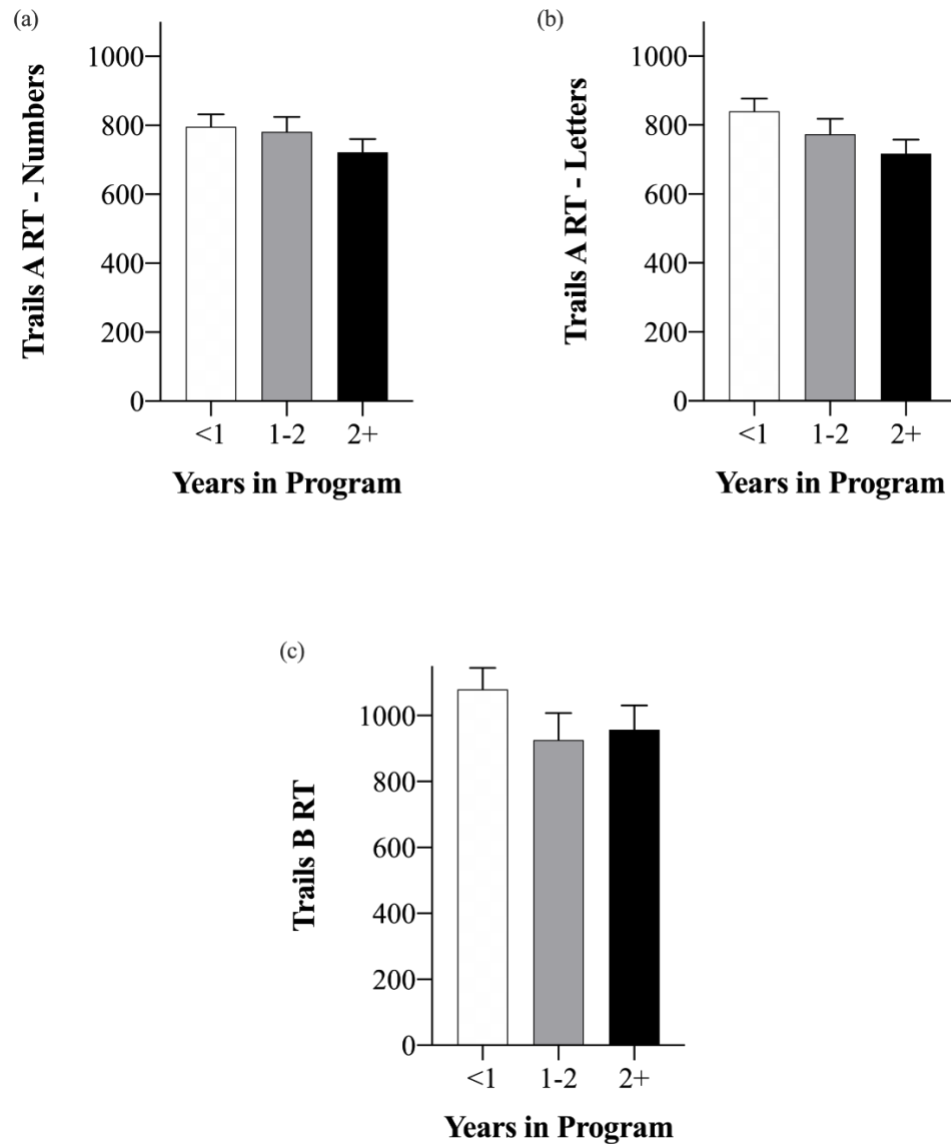
Figure 4. Reaction time (RT) on Trail-Making Test Part A, numbers (a); Part A, letters (b); and Part B (c).

Tower of Hanoi. There was no significant effect of years in program on the total number

of steps taken for all ten problems on the Tower of Hanoi ($F(2, 37)=.083$, $p=.920$,

$\eta_p^2=.005$), see Figure 5.
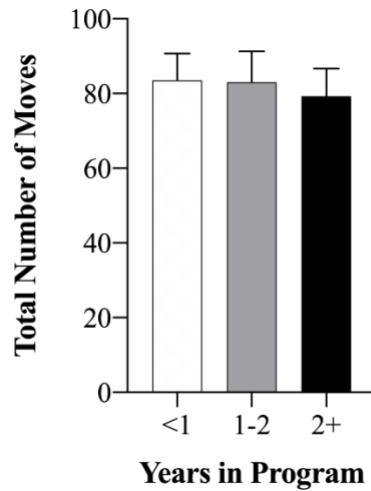
Figure 5. Total number of moves performed on the Tower of Hanoi.

2.4 Discussion

This study investigated the relationship between years of enrollment in The Roots of

Music and executive functions and self-efficacy, measures of cognitive and emotional

self-regulation, respectively. All participants were active members of the program at the

time of testing, and all came from the same socio-economic background. One year of

program enrollment was associated with higher scores on a measure of regulatory self-efficacy, and two or more years of program enrollment was associated with a measure of set shifting. No other domains of self-efficacy or executive functions were related to years of program enrollment.

This study provides evidence that one year of music programming can improve regulatory self-efficacy. Based on previous reports, these findings may lead to long-term mental health benefits among students enrolled in The Roots of Music. Regulatory self-efficacy has been shown to predict the likelihood of depression in adolescents after a four year period (Caprara et al., 2010), and is negatively associated with depressive symptoms in early adolescents (Pan et al., 2016; Dou et al., 2016; Caprara et al., 2010) and young adults (Zeng et al., 2018). Regulatory self-efficacy is also negatively associated with post-traumatic stress symptoms and suicide risk, and partially mediates the relationship between these variables and depressive symptoms (Zeng et al., 2018). The relationship between regulatory self-efficacy and post-traumatic stress may be especially important for the population sampled in this study. For instance, most of the children in The Roots of Music live in communities where gun violence is highly prevalent. Exposure to gun violence strongly predicts post-traumatic stress symptoms in school-aged children (Turner et al., 2019; Saltzman et al., 2001; Slovak & Singer, 2002; Williamson et al., 2014). Childhood experiences that cause post-traumatic stress are associated with increased likelihood of depression and suicide attempts, among a number of other negative physical and mental health outcomes (Felitti et al., 1998; Nurius et al., 2015). By improving regulatory self-efficacy, participation in The Roots of Music may provide a protective buffer against post-traumatic stress and the associated outcomes to which these

students are especially vulnerable. This also suggests that, by improving regulatory self-efficacy and possibly its associated psychological outcomes, participation in The Roots of Music may improve emotional self-regulation.

This study also shows that two years of music programming can improve the number of categories achieved in the Berg Card Sort. This measure is thought to be the gold standard for measuring set-shifting, which is a component of cognitive flexibility (Diamond, 2013). Higher set-shifting ability is typically indicated by a lower number of perseverative errors committed during the task (Berg, 1948). However, in the present study, no changes in perseverative errors were observed across years of programming. What might explain improvement in one outcome of the card sort, but not the other? In order to achieve a new category, one must respond correctly to ten consecutive trials. After ten correct trials, the feedback will change from "correct" to "incorrect," and the more readily one can detect the new rule and adhere to it, the more categories they will achieve. Because completing each trial correctly requires maintenance and updating of the rule, this particular outcome of the card sort may rely on working memory, whereas perseverative errors are more indicative of set shifting. This interpretation is supported by the fact that there were no observed differences in the other measures of cognitive flexibility included in this test battery (TMT-B, Tower of Hanoi). Furthermore, while the card sort is certainly a representative task for cognitive flexibility, working memory is required for successful execution of set shifting (Diamond, 2013). Indeed, previous studies on the Wisconsin Card Sort and working memory have shown that performance of the two tasks is positively associated (Yates et al., 2013; Lehto et al., 2003). In the current study, the Corsi blocks task was the only memory measure included in our test

battery. While some consider this a test of working memory (Fischer, 2001), others consider it a measure of short-term memory, since remembered items are not reordered or manipulated (Mammarella & Cornoldi, 2005; Vandierendonck et al., 2004; Vecchi et al, 2001). Thus, while perseverative errors may provide information regarding failures in set shifting, the number of categories achieved may have relied on updating and maintenance of working memory.

Another finding of this study is that group differences in self-efficacy and executive function emerged after different durations in the program. Whereas improvements in card sort were observed after two or more years of programming, changes in regulatory self-efficacy emerged after only one to two years. This suggests that different constructs may require different amounts of programming before they show measurable change. The developmental timing of such interventions should also be considered in this context. While general conclusions cannot be drawn about the time-courses of emotional versus cognitive changes from the current findings, this difference should be taken into account by those studying effects of music interventions over time.

This chapter provides preliminary findings from a larger-scale, ongoing study designed to examine effects of music-based mentoring on cognitive and emotional self-regulation both cross-sectionally and longitudinally. Initial power analyses for cross-sectional comparisons with high power and a moderate effect size estimated a required sample size of 150 participants. Thus, a limitation of this study is that the comparisons drawn are underpowered, and the lack of observed effects on most measures of executive functions and self-efficacy do not necessarily indicate an absence of improvement.

Despite these limitations, the current findings indicate that music programming in school-aged children is associated with enhanced executive functions and self-efficacy.

Chapter III: Executive Functions And Advanced Harmony Training

3.1 Introduction

Chapter I provided an overview of reports that demonstrate a positive relationship between music training and executive functions, a measure of cognitive self-regulation. Chapter II described similar findings in child populations, including underserved children, and showed that music programming was related to improved executive function. While most of the reports cited so far have demonstrated that musical experience is associated with enhanced executive functions, it is important to note divergent findings in this area. For instance, Slevc and colleagues (2016) reported no differences in adult musicians and non-musicians on measures of task-switching, and that musicians performed worse than non-musicians on a color-word Stroop task. Recent neuroimaging studies have also reported an absence of behavioral differences on the Stroop task between musicians and non-musicians, despite longitudinal changes in functional brain networks involved in executive functions (Hennessey et al., 2019; Sachs et al., 2017). Furthermore, in virtually every study where multiple functions are tested, some but not all tend to be significantly related to musical experience. Adding to the complexity of the issue is that the tasks that do differ between musicians and non-musicians tend to vary across studies. Why might this be?

One possible explanation for divergent findings is that investigators may be using the term "music training" too broadly, where the type of music training received by

participants varies from study to study. The terms "music training" or "musical experience" encompass an extremely broad and varied scope of experiences. Singing in a choir is an entirely different experience from teaching oneself to play the banjo. Musical notation for percussionists focuses on complex rhythmic subdivisions, whereas pianists must consider four or more pitches at a single point in time. The experience of a brass band tuba player who learns music by ear would be completely distinct from that of an orchestral tuba player who relies on sight reading. Do these qualitative differences in experience exercise different cognitive networks? If so, would one expect music-dependent improvements in certain executive functions to correspond to certain types of musical experience? The answers to these questions remain largely unknown. However, some investigators have begun to address this topic by testing whether individual functions could map onto musical experiences that rely most heavily on pitch versus rhythm.   For example, one study measured differences in inhibitory control between percussionists, vocalists, and non-musicians. In this design, the percussionists were considered the "rhythm" group, the vocalists the "pitch group," and both were compared to non-musical controls. Percussionists showed advantages in both auditory processing of rhythm, and inhibitory control, in comparisons with vocalists and non-musicians, and this percussionist advantage has been demonstrated when compared to other types of musicians as well (Slater & Kraus, 2016; Slater et al., 2017a; Slater et al., 2017b). These results suggest that inhibitory control may be selectively related to the rhythmic abilities of trained musicians, such that rhythm-based music training could lead to selective advantages in inhibitory control but not other functions. Another group tested whether pitch-based or rhythm-based music training would lead to differential outcomes in pre-

school children. In line with previous findings, the authors reported that those in the rhythm group outperformed the pitch group and non-musical controls on measures of inhibitory control (Frischen et al., 2019).

Whereas rhythm-based experience is reported to selectively engage inhibitory control, what would happen if the musical experience studied engaged all executive functions at once? One such musical practice is four-part harmonization. Four-part harmonization refers to the composition of written music across four different voices (soprano, alto, tenor, and bass). Successfully completing this task requires complex regulation of one's thoughts and actions towards each note in a musical context. When composing a harmonization, the most obvious answer will rarely be the most creative or satisfactory for the musical context of the piece as a whole, thus inhibitory control is required. Furthermore, because functional roles of musical notes are transformed by their musical context, there is a frequent requirement to shift attention both horizontally (temporally) and vertically (among parts). Thus cognitive flexibility is necessary to shift between these different perspectives. And one must attend to the direction of a piece while keeping the broad structure and direction in mind, as well as remember and apply harmonic rules and regulations to the current context, which requires working memory. Taken together, the task demands of harmonization engage all three of the core executive functions: inhibitory control, cognitive flexibility and working memory. Moreover, the cognitive demands of harmonization require integration of these functions for higher-order processes, such as selective attention, planning, and problem-solving (Diamond, 2013; Lunt et al., 2012; Collins & Koechlin, 2012).

This chapter will present a study designed to test whether harmonization ability is selectively related to a specific executive function, or globally related to all functions. Executive functions were measured using an array of tasks that assessed inhibitory control, cognitive flexibility, and working memory among musicians and non-musicians. Based on reports of a musician advantage on measures of executive functions, a musician advantage in some or all executive functions was hypothesized. In addition, a measure of ability to harmonize was developed to test whether or not musicians with high ability to harmonize performed better than musicians with low ability to harmonize on tests of executive functions.

3.2 Methods

Participants

Eighty-eight English-speaking undergraduate students (49 females, 39 males, mean age=19.31) at Tulane University participated in the study. Musically experienced participants were recruited from undergraduate harmony courses, and musically inexperienced participants were recruited through Tulane University's experiment management system.

Musical Scale Variable

To measure musical experience, a musicianship scale continuous variable was constructed using principal component analysis. Scale construction was based on responses to eight questions (Golob et al., 2017) regarding musical experience. The variables included were: importance of music in the participant's daily life (self-rated 1-

10), number of first degree relatives who are professional musicians (Nrelatives), number of instruments played (Ninstruments), total years of musical experience, years of musical experience in which the participant played consistently for at least three hours per week, average hours of playing per week, years of formal training, and ability to sight-read music (self-rated 1-10). These items were included in the scale because for each item, there was a numeric value for every participant, even if they had no musical experience. Each item was correlated with at least one other at a value greater than .3 (see Table 1; *KMO* = .838, $\chi(28)^2$=208.08, *p*<.001) suggesting reasonable factorability. Inspection of the scree plot indicated a single factor (see Figure 6), onto which all variables loaded high (Importance = .539, Nrelatives = .584, Ninstruments = .826, Years Experience = .914, Years Instrument 1 = .826, Hours Per Week = .654, Years Formal Training = .901, Reading Ability = .929). This component explained 61.72% of the total variance in scores. The factor loading matrix for the single component is presented in Table 2. Internal consistency for the 8-item scale was strong (α = .902). A Music Scale Variable (MSV) score ranging from -2 to +2 was computed for each participant, and indicated scores on the single musicianship component.

		Importance of Music	# Pro. Musician Relatives	# Instruments Played	Years of Musical Experience	Years on Primary Instrument	Average Hours of Practice Per Week	Years of Formal Training	Sight-Reading Ability
Importance of Music	r	1	0.381	0.376	0.470	0.461	0.269	0.427	0.443
	p		0.015	0.017	0.002	0.004	0.093	0.007	0.005
# Professional Musician Relatives	r	0.381	1	0.446	0.462	0.214	0.431	0.544	0.377
	p	0.015		0.004	0.003	0.204	0.006	0.000	0.018
# Instruments Played	r	0.376	0.446	1	0.619	0.597	0.631	0.618	0.684
	p	0.017	0.004		0.000	0.000	0.000	0.000	0.000
Years of Musical Experience	r	0.470	0.462	0.619	1	0.860	0.516	0.803	0.758
	p	0.002	0.003	0.000		0.000	0.000	0.000	0.000
Years on Primary Instrument	r	0.461	0.214	0.597	0.860	1	0.464	0.719	0.774
	p	0.004	0.204	0.000	0.000		0.000	0.000	0.000
Average Hours of Practice Per Week	r	0.269	0.431	0.631	0.516	0.464	1	0.481	0.553
	p	0.093	0.006	0.000	0.000	0.000		0.000	0.000
Years of Formal Training	r	0.427	0.544	0.618	0.803	0.719	0.481	1	0.702
	p	0.007	0.000	0.000	0.000	0.000	0.000		0.000
Sight-Reading Ability	r	0.443	0.377	0.684	0.758	0.774	0.553	0.702	1
	p	0.005	0.018	0.000	0.000	0.000	0.000	0.000	

Table 1. Correlations among musicianship variables.
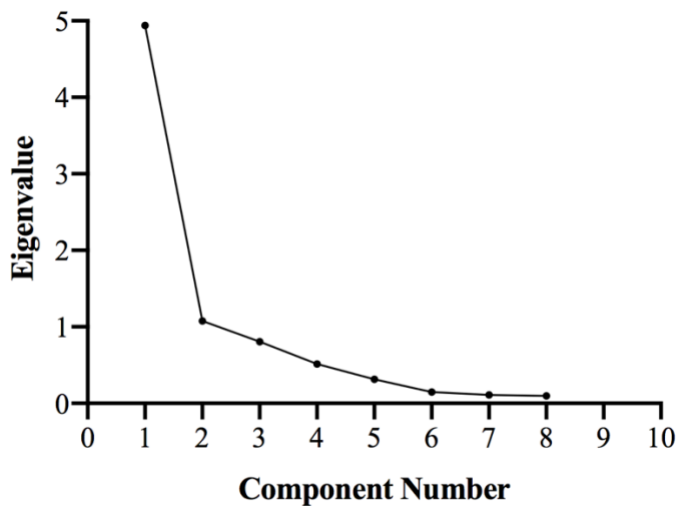
Figure 6. Scree plot resulting from 8 musicianship variables.

	Component 1
Importance of Music	.539
# Professional Musician Relatives	.584
# Instruments Played	.826
Years of Musical Experience	.914
Years on Primary Instrument	.826
Average Hours of Practice Per Week	.654
Years of Formal Training	.901
Sight-Reading Ability	.929

Table 2. Factor loading matrix for the single component derived from the 8 musicianship variables.

Assessment of Executive Functions

All participants completed a computerized battery of cognitive tests commonly used to measure EFs including the Go/No-Go, Stroop, Simon task, Tower of London, and the Backwards Digit Span. These tests were chosen in order to include separate, representative assessments of inhibitory control, working memory, and cognitive flexibility. All tasks were accessed through the Psychology Experiment Building Language (PEBL) software. A description of each task and the component(s) measured follows:

(a) Go/No-Go

The go/no-go task measures inhibitory control in a stop/go paradigm (Logan et al., 1984). Participants were presented with either a P or an R, and instructed to press a computer key only when presented with a P. P's were presented for 80% of trials, in order to establish an expected key press response to a visual stimulus. The number of key presses to R (inhibition failures) was measured.

(b) Stroop

The Stroop task measures inhibitory control of attention by creating interference between a stimulus and its required response (Stroop, 1935; MacLeod, 1991). A numerical Stroop task was used for the current study in which participants were presented with the numbers 1, 2, or 3 and were instructed to press the number on the keyboard corresponding to the number of characters in each trial. For example, for "111", the correct response would be 3, and for "3" the correct response would be "1." Participants were presented with congruent (66.6%) and incongruent trials (33.3%)

("333" being congruent, "111" being incongruent), and the differences in accuracy and reaction time between the two conditions were measured

(c) Simon

Similar to the Stroop task, the Simon task manipulates stimulus-response compatibility, requiring the participant to engage inhibitory control and suppress impulsive responses in order to respond correctly (Simon & Berbaum, 1988). Participants were presented with a blue or red circle, either of which could appear at various positions on an invisible number line across the screen (from far right to far left). Participants were instructed to press the left shift key for a blue circle, and the right shift key for a red circle. The difference in accuracy and reaction time between congruent (blue – left, red – right) and incongruent (blue – right, red – left) trials were measured.

(d) Tower of London

The Tower of London task assesses cognitive flexibility via problem-solving and planning abilities. Participants were presented with two sets of three rings, one set was the "goal state," and one set was the workspace (Shallice, 1982). Participants were instructed to move the rings in the workspace into the configuration shown in the goal state. Participants were allowed 3-4 moves per trial, depending on trial complexity, to get the rings into the goal state. The limit on moves was chosen to necessitate deliberate planning and problem-solving. The total number of problems solved was measured.

(e) Backwards Digit Span

The backwards digit span task measures working memory (Kaplan et al., 1991). Participants were presented with a list of three numbers, asked to memorize the list, and then to type the list on the computer from memory in the opposite order in which it was presented. If the participant responded correctly, then the list length increased by one digit for each correct response. The maximum number of digits that the participant entered correctly was measured.

Assessment of Harmonic Ability

To assess harmonic ability, an eight measure melody was developed a composition professor at Tulane University. Participants were asked to attempt the harmonization exercise if they had ten or more years of continuous musical experience. This criterion was chosen because it would allow meaningful conclusions to be drawn about effects seen within musicians, and because completing this harmonization assessment would require extensive knowledge of classical Western European harmonic practices that could only be attained through high-level training and experience. Musically experienced participants were given eight measures of a four-part staff (Soprano, Alto, Tenor, Bass), with the provided melody written into the soprano line, and the alto, tenor and bass lines left blank. They were instructed to harmonize the soprano line in four voices in accordance with the classical rules and conventions of Western harmony. Harmonizations were scored on the basis of six criteria,: (1) creativity/imagination, (2) sophisticated solutions with regard to selections of specific harmonic structures that result in desired harmonic motion, (3) ability to construct balanced phrases characterized by a sense of motion and direction, (4) ability to shape interesting horizontal lines, (5) ability

to interpret and to simultaneously handle multiple rules which, at times, may require exceptions or alternative solutions, (6) ability to recall multiple rules with regard to horizontal voice-leading, doubling spacing, and range.

Responses were scored 0-4 for each of these six criteria as follows: Participants were scored a 0 = no effort and understanding of the concept; 1 = minimal effort was present but the concept was severely misunderstood or unrealized in the harmonization; 2 = some effort and understanding were present but parts were executed poorly or incorrectly; 3 = effort and understanding were present and the result was technically correct; 4 = effort and understanding were both maximally present and the result was both technically correct and musically exceptional. Accordingly, the highest score possible was 24, resulting from scoring a 4 in each area, and the lowest possible score was 0. Participants were given as long as they needed to complete the exercise, with times ranging from 5-75 minutes. Figure 7a shows an example of a low scoring harmonization, and Figure 7b shows an example of a high scoring harmonization. Intra- and inter-rater reliability were assessed. 33 harmonizations were re-scored by the original rater (intra-rater), and by a Composition professor unaffiliated with the study (inter-rater). Harmonizations were de-identified using participant ID codes and were re-scored without access to the original scoring sheet.

Figure 7. Typical low (a) and high (b) scoring examples of the harmonization

assessment.

The unique issue of operationalizing harmonic skill is that if every composer precisely followed all Western rules and conventions, then all of their music would sound the same. For instance, while one will never find parallel fifths in a Bach composition, Debussy utilized them frequently to cultivate the style that made him an exceptional composer. Thus, simply knowing the rules and how to follow them is not all that is involved with harmonic skill. The criteria presented here were selected to not only highlight technical prowess, but also creativity and the capacity for innovation, which are essential for mastering harmonic composition.

Procedure

After obtaining informed consent, participants completed the musical experience survey (Golob et al., 2017), then completed the cognitive task battery in a pseudo-random order. Participants who met the criteria described above for a highly experienced musician were asked to complete the harmonization assessment (n=52).

Statistical Analysis

Correlation analyses were used to test associations between music scale score and scores on each cognitive measure. Correlation analyses were then used to test the associations between harmonization score and each cognitive measure that was significantly related to music scale score.

3.3 Results

Cognitive Evaluation

Correlations were tested between the Musical Scale Variable (MSV) and each

cognitive measure and significance levels were adjusted for multiple comparisons using

Holm's sequential Bonferroni adjustment (Holm, 1979). There was a significant positive

correlation between Tower of London Score and MSV ($r=.38$, $p=.002$, $N=88$). This

effect is illustrated in Figure 8. No other significant correlations were detected between

MSV and other measures of executive function, including Backwards Digit Span ($r=.234$,

$p=.182$, $N=86$), Go/No-Go ($r=.078$, $p=.476$, $N=85$), Stroop Task Accuracy ($r=-.102$,

$p=.351$, $N=86$), Stroop Task Reaction Time ($r=.016$, $p=.886$, $N=86$), Simon Task

Accuracy ($r=.141$, $p=.191$, $N=88$), and Simon Task Reaction Time ($r=.152$, $p=.158$,

$N=88$).

A correlation analysis indicated a significant relationship between Harmony Score

and Tower of London Score ($r=.355$, $p=.010$, $N=52$). This effect is illustrated in Figure

9. Regression analysis indicated that Harmony Score did not moderate the relationship

between Tower of London Score and MSV, as the predictor of the interaction term MSV

x Harmony Score was not significant ($B=.070$, $p=.748$). Correlations conducted between

the MSV and demographic variables did not indicate relationships between MSV scores

and Sex ($r=.077$, $p=.477$, $N=88$) or between MSV and Age ($r=-.003$, $p=.981$, $N=88$).

Harmony Score was also unrelated to Sex ($r=-.108$, $p=.445$, $N=52$) and Age ($r=-.122$,

$p=.390$, $N=52$).
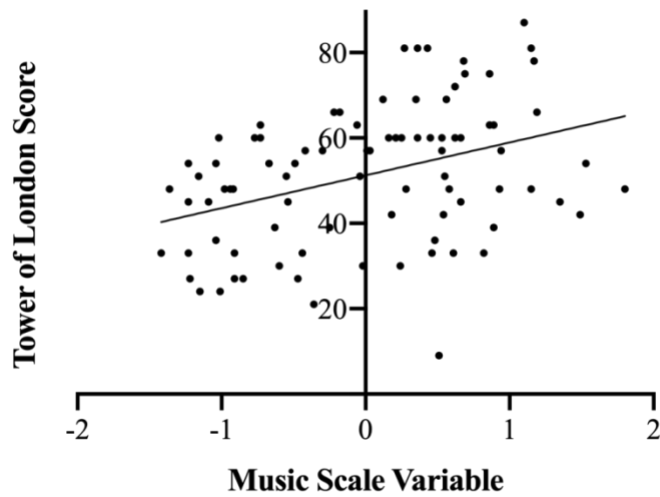
Figure 8. Correlation between scores on the Tower of London and Music Scale

Variable, $r=.38$, $p=.002$.
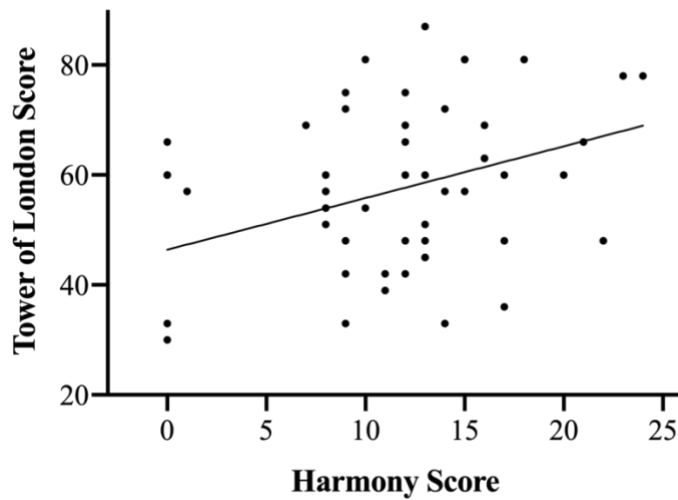
Figure 9. Correlation between scores on the Tower of London task and harmonization

assessment, $r=.355$, $p=.010$.

Reliability Evaluation

Intra- and inter-rater reliability were assessed to evaluate reliability of the harmony assessment. To test intra-rater reliability, 50% of the completed harmony assessments were randomly selected and re-scored by the original rater. The original and rescored values were highly correlated ($r=.856$, $p<.001$, $N=26$), suggesting strong intra-rater reliability. This relationship is shown in Figure 10a. Original harmony scores were also positively correlated with re-scored values from an additional rater ($r=.538$, $p=.004$, $N=26$), suggesting high inter-rater reliability. This relationship is shown in Figure 10b.

(a)

(b)
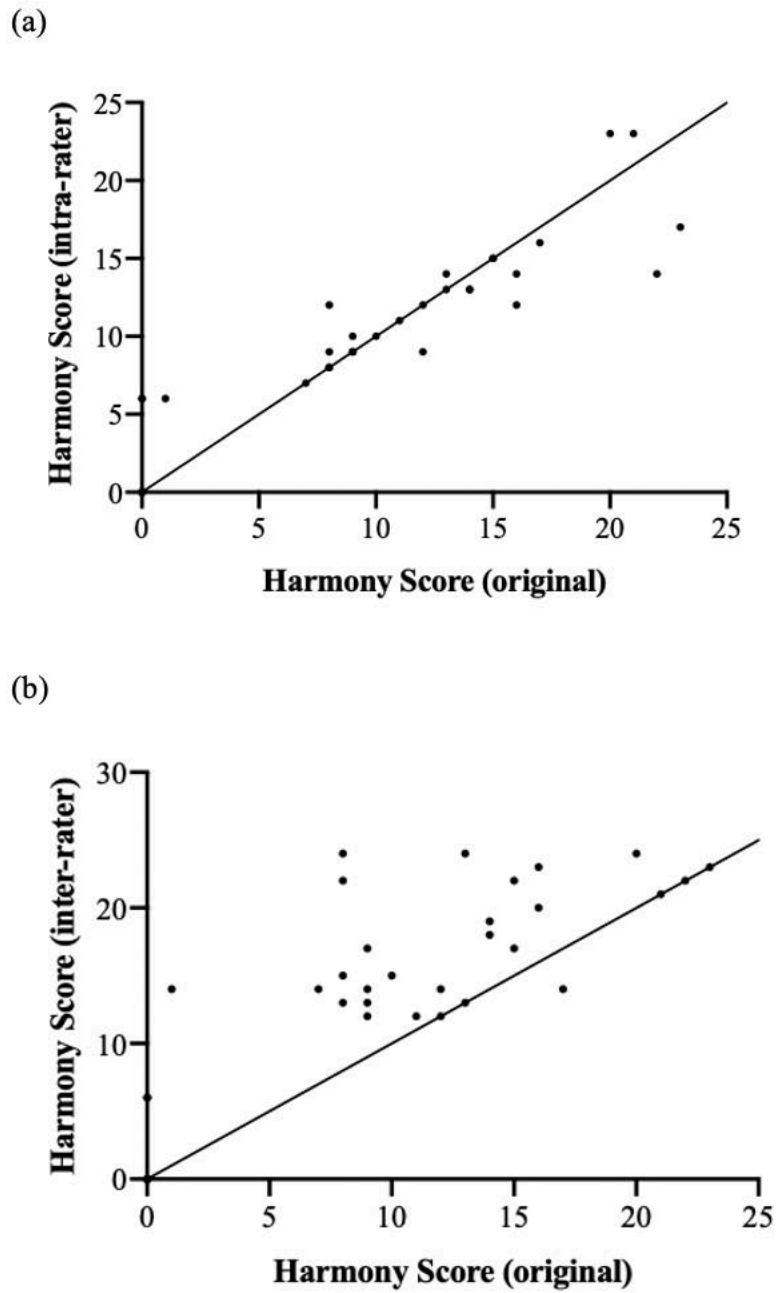
Figure 10. Correlations between original harmony scores and re-scores by the same rate (a) and a different rater (b).

3.4. Discussion

The current findings indicate that music training is positively associated with performance on the Tower of London task, a measure of planning and problem solving. Musicianship was not related to performance of the Backwards Digit Span, Stroop, Simon, or Go/No-Go tasks. Among participants with high levels of musical experience, harmony scores were positively correlated with scores on the Tower of London task. These findings provide the first evidence that harmonic ability is related to executive functions.

The current findings are consistent with reports that musical experience is related to executive function (Gardiner et al., 1996; Bialystok & DePape, 2009; Moreno et al., 2011; Alain et al., 2018); in specific, planning and problem-solving (Drake & Palmer, 2000; Berti et al., 2006; Sachs et al., 2017). These findings are not consistent with reports of enhanced working memory and inhibitory control among musicians (Moreno et al., 2009, 2014; George & Koch, 2011; Slater et al., 2017a). This discrepancy may be due to the nature of musical training that participants received in the current study compared with others. Recent research has begun to address this issue. For example, a comparison of the effects of rhythm- and pitch-based music training on executive functions in young children revealed that only the rhythm group showed a significant improvement in inhibition (Frischen et al., 2019), indicating that the type of training received can influence which cognitive outcomes are observed. Previous studies that demonstrated a relationship between rhythmic processing and inhibitory control deliberately recruited musicians with extensive percussion training (Slater et al., 2017a;

Slater et al., 2018) or vocal training (Slater et al., 2017b) in order to draw comparisons based on the amount of rhythm-based musical training. Because our primary objective was to study harmonic ability, university music students currently enrolled in harmony courses were recruited. Since most of our musically experienced participants came from this population, it is possible that harmony training facilitated our effect of musical training on the Tower of London, but not other tasks. This may explain why only planning and problem-solving were related to overall musicianship, despite previous reports of other functions being related to musical training. Overall, the current findings add to the growing body of evidence that music training is associated with advantages in higher order cognitive functions. However, the observed differences from previous studies highlight the need for considering the elements of music training received by participants in future studies.

Among musically experienced participants, the current results indicate that scores on the Tower of London, but not the other measures of executive functions, were related to scores on the harmony assessment. Planning and problem-solving, which are central to both the Tower of London task and harmonization, are considered by many authors to be higher-order executive functions that build upon the three core components (Diamond, 2013; Lunt et al., 2012; Collins & Koechlin, 2012). Indeed, successful completion of the Tower of London task requires inhibitory control to prevent an impulsive response before the correct path is planned, cognitive flexibility to imagine and select among alternative outcomes, and working memory to mentally retrace the sequence of moves. Successful harmonization also requires integration of inhibitory control, cognitive flexibility, and working memory. In contrast, the Backwards Digit Span and the Go/No-Go tasks more

selectively measure the individual functions of working memory and inhibitory control, respectively, and successful performance of these tasks does not likely require simultaneous coordination of multiple cognitive processes. Therefore, harmonization and the Tower of London task both require integration of multiple executive functions. This may explain our finding that harmonization is related to performance of the Tower of London, but not to performance of tasks that more selectively measure inhibitory control or working memory.

That being said, no evidence that harmony training moderates the relationship between musical experience and planning/problem-solving was found. This suggests that harmony training is not influencing the relationship between musical experience and executive function. It may be more likely that participants with better planning and problem-solving abilities are more likely to score highly on the harmonization assessment. Indeed, previous reports suggest that external variables, such as intelligence, can predict whether children are more likely to take music lessons and perform highly on tests of executive functions (Schellenberg, 2011). However, it is still possible that other elements of musical experience can explain the observed relationship between musical experience and planning/problem-solving. Future studies should systematically compare how different elements of music training impact executive functions to establish causality.

A methodological contribution of the current study is the development of a scale for defining musicianship that has advantages over the categorical assignment of participants to groups of musicians and non-musicians. First, there are vast individual differences in levels of musical experience, and use of a scale permits investigation of a

range of experience that better represents the population. A musicianship scale also allows for the reduction of several aspects of musical experience to a single value while maintaining fidelity to the experiences that contribute to musicianship. In addition, aspects of musical experience that are included in the scale are assessed for reasonable factorability, thus justifying use of items in a single scale.

Overall, the current study extends previous reports that music training is related to improvements in cognitive self-regulation, measured by executive functions, and provides evidence of a relationship between harmonization and planning and problem solving. Harmonization practice may facilitate coordination of individual executive functions resulting in general enhancement of planning and problem-solving skills. Alternatively, those with high planning and problem-solving abilities may be predisposed to better harmonization. Although further study with random assignment to harmony training is necessary to establish a causal relationship, the current findings suggest that harmonization training may be a useful therapeutic strategy for targeting executive dysfunction, especially among those with impairments of planning and problem-solving.

Chapter IV: Perceived Chronic Stress, Mental Illness, And Physiological Responses To Acute Stress In Musicians And Non-Musicians

4.1 Introduction

Thus far, evidence for music-related benefits to cognitive and emotional measures of self-regulation has been presented. However, another measure of self-regulation that has yet to be discussed is how individuals react to and recover from stressful situations. Individuals vary in their reactivity to and recovery from a physiological stress response (Earle et al., 1999; Braungart-Rieker & Stifter, 1996), and this variation provides insight into physiological mechanisms of self-regulation. In order to investigate the relationship between musical experience and self-regulation from a physiological perspective, the following chapter will address differences between musicians and non-musicians in physiological stress reactivity and recovery in response to an acute, psychological stressor.

Common psychological stressors, such as public speaking, running late, or being stuck in traffic, elicit a cascade of physiological responses much like those experienced when under physical threat or injury (see Dhabhar, 2014; Glaser & Kiecolt-Glaser, 2005; Liu et al., 2017; Marsland et al., 2017; Segerstrom & Miller, 2004; and Steptoe et al.., 2007 for detailed reviews). In response to these psychological stressors, the body activates the sympathetic nervous system (SNS) and hypothalamic-pituitary-adrenal (HPA) axis. Activation of the SNS is fast, and increased sympathetic activity, such as increased heart rate, blood pressure, and respiration, typically occurs right away (Smith & Vale, 2006). HPA axis activation is comparatively slow, and results in the release of cortisol. Peak cortisol levels are seen approximately 15-25 minutes after experiencing a

stressor (Ramsay & Lewis, 2003; Izawa et al., 2013). After this reactive cortisol peak, circulating cortisol binds to glucocorticoid receptors throughout the central nervous system to inhibit subsequent HPA cortisol release via a delayed feedback system (Smith & Vale, 2006). This feedback system unfolds over several minutes, and stress recovery (cortisol levels returning to baseline) is typically observed between 40 and 60 minutes post stressor.

Acute stress reactivity and recovery can both be modulated by behavioral techniques (Wallace & Benson, 1972; Braungart-Rieker & Stifter, 1996; Manzoni et al., 2008). Music listening is commonly discussed for having stress-relieving effects (ie: Ooishi et al., 2017; Koelsch et al., 2011; Tabrizi et al., 2012; Nilsson et al., 2009), and musical experience may influence the modulation of acute stress markers such as cortisol. However, few studies have investigated the role that active musical experience, rather than music listening, has on cortisol levels during and after an acute psychological stressor. Laohawattanakun and colleagues (2011) measured adolescent musicians' and non-musicians' cortisol levels at baseline and immediately before an academic exam. They found that while the groups did not differ at baseline, musicians demonstrated lower salivary cortisol than non-musicians immediately before the exam. Killough et al (2016) used a musical audition-like paradigm to study differences in stress reactivity and recovery in highly experienced versus minimally experienced musicians. These authors found that while reactivity was not different between highly experienced and less experienced musicians, recovery was, such that more experienced musicians showed a quicker return to baseline. Taken together, these reports suggest that musical experience may attenuate cortisol modulations in response to an acute psychological stressor.

However, these reports do not elucidate whether musical experience influences reactivity or recovery of cortisol levels following acute stress. One study suggests that musical experience impacts stress reactivity (Lawhawattankun et al., 2011), while the other suggests that it selectively impacts recovery (Killough et al., 2016). Furthermore, Lawhawattankun et al. (2011) measured stress reactivity in response to an academic exam. Previous reports indicate that academic exams can lead to elevations in HPA activity lasting several days or weeks (Bosch et al., 2004; Murphy et al., 2009; Duan et al., 2013). Therefore, it is unclear whether the observed difference in musicians and non-musicians was due to acute psychological stress or prolonged changes to the system that occurred in anticipation of the exam. Furthermore, in this study, recovery was not measured. In Killough's study (2016), the authors only included musicians in their sample, and their stressor was also musical. Thus, their findings cannot explain benefits to the stress response that are unique to musical experience. Taken together, there is a need for investigating whether musical experience benefits acute stress reactivity and/or recovery, as well as comparing experienced musicians to non-musician controls.

In addition to physiological markers of acute stress, there are limited findings regarding musical experience and perceived chronic stress and psychological well-being. One study, however, did compare anxiety and depression symptoms in a large sample of professional musicians to symptoms of individuals in the general workforce. Overall, musicians demonstrated higher levels of psychological distress when compared to a group of managers, technicians, and non-musical academics (Vaag et al., 2016). Within musicians, vocalists, soloists, and lead performers displayed the highest prevalence rates of anxiety and depression (Vaag et al., 2016), suggesting that more individual

performance pressure may lead to negative psychological outcomes. A similar study on professional musicians reported higher perceived emotional demands, lower social support, lower sense of community, and lower job satisfaction in symphony orchestra musicians when compared to those in the general workforce (Holst et al., 2012). Thus, whereas previous reports suggest that musicians demonstrate an attenuated acute physiological stress response, investigations of long-term distress suggest that musicians have poorer outcomes on perceived measures of chronic stress and psychological distress. Depressive symptoms and perceived chronic stress represent measures of emotional self-regulation, and such findings suggest that professional musicians may actually have poorer emotional regulation than non-musicians. This is consistent with previous literature that reports divergence between physiological and perceived markers of stress (Cohen et al., 2000; Hjortskov et al., 2004; Lackschewitz et al., 2008; Schlotz et al., 2008).

The current study tested whether musicians differ from non-musicians in physiological self-regulation via their physiological response to the Trier Social Stress Test (TSST), and emotional self-regulation via measures of perceived chronic stress and depressive symptoms. The TSST is a standardized and reliable technique used to elicit an acute stress response to social evaluation (Kirschbaum et al., 1993; Aschbacher et al., 2011; Marsland et al., 2017; Puterman et al., 2014). Perceived chronic stress and depressive symptoms were measured before the TSST was administered. Salivary cortisol levels were measured before and at multiple timepoints after the TSST. It was hypothesized that musicians would exhibit a lower physiological stress response, represented by a lower cortisol peak and a faster recovery to baseline, when compared

with non-musicians. It was also hypothesized that musicians would score higher than

non-musicians on measures of perceived chronic stress and depressive symptoms.

4.2 Methods

Participants

Participants consisted of undergraduate students at Tulane University recruited through

Tulane's Psychological Research Participation System and the Tulane marching band. 61

participants were recruited, and three were excluded for having intermediate levels of

musical experience. The final sample size included 58 participants ranging in age from

18-23 (31 females, 27 males).   Participants completed a medical history questionnaire to

rule out potential periodontal, gum, or other chronic illnesses that could interfere with

saliva collection.

Questionnaires

Subject variables: Several lifestyle variables may influence modulations of

cortisol levels in response to an acute social stressor. Participants completed a medical

history questionnaire that asked about medications, diagnoses of psychiatric disorders,

acute illness, injury, or infection and lifestyle behaviors such as smoking and alcohol

consumption. Female participants were also asked to provide information about birth

control, pregnancy, and the current stage of their menstrual cycle. Because a social

stressor was used to induce an acute stress response, all participants also completed the

Cheek and Buss Shortened Shyness and Sociability Scale (Crozier, 2005).

Musicianship: Participants were grouped as musician or non-musician based on responses to a musical experience survey (adapted from Golob et al., 2017) that measured how often participants practice, study, receive formal training, and perform music. Participants who played continuously on a primary instrument for at least 7 years, practiced at least 3 hours per week, started at or before the age of 11, and still currently play were considered musicians. Participants who had less than three cumulative years of musical experience were considered non-musicians. Three participants reported between 3 and 7 years of musical experience, and were excluded from all between-group analyses. These criteria were based on those used in previous reports of differences between musicians and non-musicians (Zuk et al., 2014; Clayton et al., 2016; Killough et al., 2016).

Perceived chronic stress, depressive symptoms, and perceived acute stress: Before exposure to the experimental stressor, participants completed the Perceived Stress Scale (PSS) (Cohen et al., 1983) as a measure of perceived chronic stress, and the Beck Depression Inventory (BDI) (Beck et al., 1961) as a measure of depressive symptoms. As a measure of perceived acute stress, participants completed the 6-item state anxiety portion of the State-Trait Anxiety Inventory (STAI: Marteau & Bekker, 1992) each time they provided a saliva sample.

Assessment of Physiological Stress Reactivity and Recovery

Physiological stress was measured via salivary cortisol, heart rate, and blood pressure over time, before and after exposure to an acute psychological stressor. The Trier Social Stress Test (TSST: Kirschbaum et al., 1993) was used to induce an acute

stress response. In the TSST, participants were brought to a separate room from the laboratory and greeted by a panel of three people and a video camera. Participants were asked to assume the role of a job applicant, and act as if the panel members were their prospective managers. Participants were instructed to prepare a five minute speech to convince the panel that they were right for the job, and to deliver their speech to the camera. Participants were told that their video tape would be analyzed by a voice and behavior expert. This was deception, as the videos were never actually analyzed. Participants were given 10 minutes to prepare their speech, during which time they were brought back to the laboratory. After 10 minutes, they were brought back to the video camera room and would deliver their speech while a timer was set to five minutes. If a participant stopped talking with time remaining on the timer, the panelists would remain silent for 20 seconds. If the participant did not speak after 20 seconds, a panelist would say: "You still have time left, please continue." After the five minute speech, participants were asked to count backwards from 1,022 by 13 as quickly as possible. Again, the timer was set to five minutes. If the participant made a mistake, a panelist would say: "Stop. 1,022." and the participant was instructed to start again from the beginning. After the five minutes of mental arithmetic, the TSST was complete.

Saliva Collection

In order to prevent contamination of saliva samples, participants were instructed not to eat, chew gum, smoke, or drink anything other than water at least 1 hour before their scheduled testing session. Saliva collections always took place between 1pm and 5pm to minimize changes in cortisol levels reported to occur throughout the day. For

each saliva collection, participants were asked to provide 1mL of un-stimulated saliva via

passive drool into SalivaBio Passive Drool Method (Salimetrics, Carlsbad, CA)

containers. Each time saliva was collected, the experimenter also measured heart rate

and blood pressure to provide additional measures of stress reactivity and recovery.

Samples were stored in a freezer set to -70° C until analysis.

Procedure

All study protocols were approved by Tulane University's Institutional Review

Board. Participants provided written informed consent immediately upon entering the

laboratory. During the initial consenting procedure, participants were told that the study

aimed to measure differences in endocrine markers in musicians and non-musicians, and

that they would complete a verbal speech and mathematics task during the study.

Information regarding the TSST was kept deliberately vague, so that participants would

not experience anticipatory stress before their baseline saliva collection. After providing

consent, participants filled out the packet of questionnaires probing medical history,

shyness, perceived stress, depressive symptoms, and musical experience. When they

were finished with the questionnaire packet, participants provided their first saliva

sample. This sample served as their baseline measurement. Then, participants completed

the TSST. After the TSST, participants were brought to a third room (neither the stress

room nor the saliva collection room), and watched a nature documentary for one hour.

During this hour, saliva samples were collected intermittently to monitor recovery after

experiencing the stressor. Table 3 depicts a timeline of saliva collections throughout the

study procedure. At the end of the recovery period, participants were debriefed on the

purpose of the TSST, and informed that no video recording was saved from their speech. After debriefing, participants were asked to provide consent again, and given the option to remove their data from the study if they were uncomfortable with the deception used.

Minutes after TSST	Procedure
-20	Informed consent, questionnaires
0	First saliva collection, immediately before TSST
30	Second saliva collection, immediately after TSST
60	Third saliva collection, after 30 minutes of recovery
90	Fourth saliva collection, after 60 minutes of recovery

Table 3. Timeline of saliva collections relative to stressor onset.

Saliva Sample Analysis

Samples were analyzed for cortisol using Enzyme-Linked Immunosorbence Assay kits (ELISA, Salimetrics, Carlsbad CA) with sensitivity of <7ng/dL for cortisol. Samples were aliquoted and stored at -70˚ C after collection. Right before analysis, samples were thawed, vortexed and centrifuged at 1500g to remove precipitated mucins and other particulates. Samples were run in duplicate and the mean was taken as the

marker concentration for that sample. Since total salivary protein concentrations have been shown to vary between samples (Sjögren et al, 2006) and in response to acute stress (Naumova et al, 2012, Naumova et al, 2014), the absorbance values found for cortisol were adjusted for total protein concentration in each sample. Protein concentrations were obtained using a bicinchoninic acid (BCA) protein assay, and measured in milligrams of protein per milliliter of saliva. To adjust cortisol levels for total salivary protein, cortisol concentrations (ng/mL) were divided by total protein concentrations (mg/mL) to obtain nanograms of cortisol per milligram of total protein (ng/mg).

Statistical Analysis

Between group differences in musicians and non-musicians were assessed with Independent Samples T-Tests for continuous subject variables (such as age), and Pearson's X^2 tests for categorical subject variables (such as sex). Repeated measures data were analyzed at four timepoints: T0 - baseline, T30 – immediately post-stressor or 30 minutes from the onset of the stressor, T60 – 60 minutes from the onset of the stressor, and T90 – 90 minutes from the onset of the stressor (see Table 3). Generalized Estimating Equations (GEE) were used to analyze all repeated measures data, which included cortisol levels, total protein, heart rate, blood pressure, and perceived acute stress. For each variable, values greater than three standard deviations from the group mean were considered and removed for each dependent measure.

The GEE model included Subject ID as the subject variable, Time as the within-subjects variable, and Time and Group (musicians, non-musician) as predictors. Because the data were not normally distributed, GEE was modelled using the gamma distribution

with a log link function, and the working correlation matrices were unstructured. GEE was selected over repeated-measures ANOVA for two reasons: 1) GEE accommodates participants with missing data, such that if cortisol at one timepoint was missing or an outlier, the participant's three remaining timepoints could still be included in the analysis, and 2) cortisol data were not normally distributed, and GEE can accommodate non-normally distributed data. *Aposteriori* comparisons were conducted as pair wise contrasts following each GEE, and adjusted using the Sequential Bonferroni correction. All data are represented as Mean ± SEM, and values of $p < 0.05$ were considered significant for all analyses.

4.3 Results

Subject Variables.

Musicians and non-musicians did not significantly differ by age (t_{56}=-1.371, p=.176), education (t_{56}=1.373, p=.175), or sex (X^2(1, N=58)=2.441, p=.188). Musicians and non-musicians were also compared for differences in lifestyle factors that could impact cortisol levels. No group differences were detected for regular cigarette smoking (X^2(1, N=58)=.432, p=.511), consuming caffeine on the day of testing (X^2(1, N=58)=2.281, p=.516), exercising on the day of testing (X^2(1, N=58)=.950, p=.330), any acute illness, injury, or infection (X^2(1, N=58)=.014, p=.905), or scores on the Cheek and Buss Shyness Inventory (t_{56}=.529, p=.599). Female participants in each group did not differ on whether they were on birth control (X^2(1, N=31)=5.460, p=065), experienced irregular periods (X^2(1, N=31)=2.441, p=.295), or the number of days since their last

period ended ($t_{10.002}$=.922, p=.378). No female participants in the sample were pregnant

at the time of testing.

Perceived chronic stress, depressive symptoms, and diagnoses of mental disorders.

Musicians reported significantly lower scores on the PSS ($t_{44.370}$=-2.389, p=.021)

and BDI ($t_{37.528}$=-2.238, p=.031) than non-musicians. These differences are illustrated in

Figures 11 and 12. Furthermore, non-musicians were significantly more likely than

musicians to have been diagnosed with a mental disorder (X^2(1, N=58)=10.443,

p=.001). A summary of all musician/non-musician comparisons can be found in Table 4.

Because PSS scores, BDI scores, and having been diagnosed with a mental

disorder were significantly different between groups, correlations were used to test

whether they were significantly related to cortisol at each timepoint. Neither PSS nor

BDI scores were significantly related to cortisol at any timepoint (see correlation matrices

in Table 5 and Table 6, respectively). GEE revealed that having had a mental disorder

was significantly related to cortisol across timepoints (Wald X^2 (1, N=58)=5.495,

p=.019). Because this factor was significantly different between groups and significantly

related to cortisol, Mental Disorders were included in the cortisol analysis as a

covariate. PSS scores and BDI scores were not treated as covariates, as they were not

significantly related to cortisol.

PSS
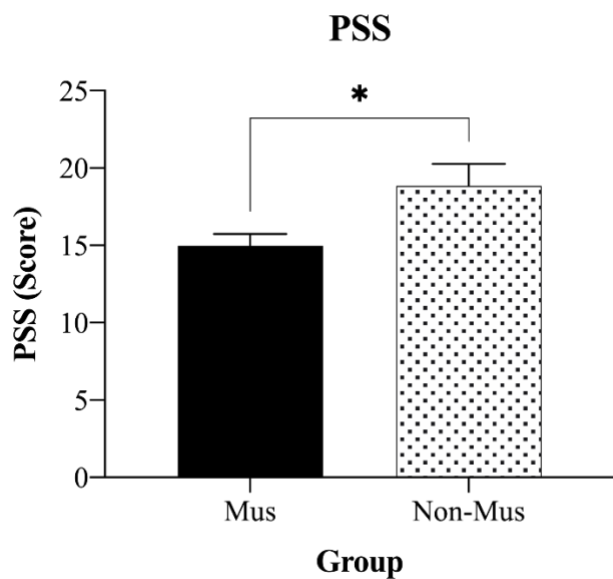
*p<.05

Figure 11. Scores on the Perceived Stress Scale (PSS) in musicians and non-musicians.

BDI
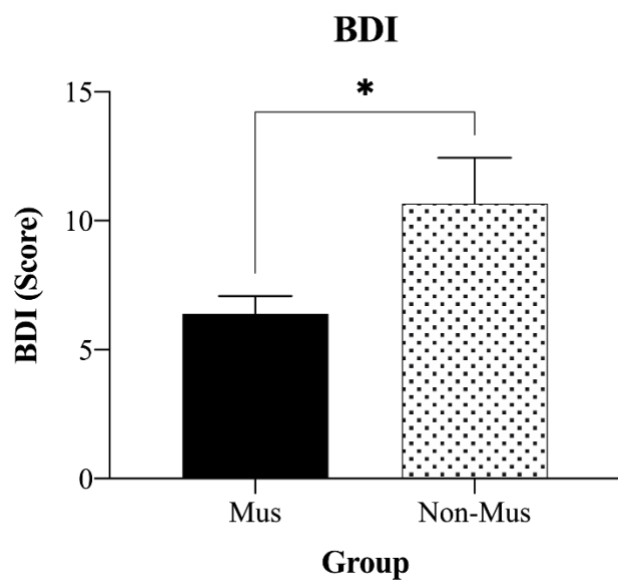
*p<.05

Figure 12. Scores on the Beck Depression Inventory (BDI) in musicians and non-musicians.

Subject Variable	Mean/Count		Test Statistic	p-value
	Mus	**Non-Mus**		
Age	*M*=18.89 *SD*=0.96	*M*=19.23 *SD*=0.94	$t(56)$=-1.371	p=.176
Sex	F: 12 M: 16	F: 19 M: 11	$X^2(1) = 2.441$	p=.118
Highest education level completed	*M*=13.64 *SD*=0.78	*M*=13.93 *SD*=0.83	$t(56)$=-1.373	p=.175
Have you ever been clinically diagnosed with a mental disorder?	Y: 3 N: 25	Y: 15 N: 15	$X^2(1) = 10.443$	p=.001**
Perceived Stress Scale score	*M*=14.96 *SD*=4.08	*M*=18.83 *SD*=7.80	$t(44.370)$=-2.389	p=.021*
Beck Depression Inventory Score	*M*=6.39 *SD*=3.67	*M*=10.67 *SD*=9.75	$t(37.528)$=-2.238	p=.031*
Shyness Inventory Score	*M*=34.68 *SD*=9.29	*M*=33.33 *SD*=10.04	$t(56)$=.529	p=.599
Do you regularly smoke cigarettes more than once per month?	Y: 3 N: 25	Y: 5 N: 25	$X^2(1) = .432$	p=.511
For female participants: How many days has it been since your last period ended?	*M*=27.00 *SD*=39.00	*M*=15.33 *SD*=11.20	$t(10.002)$=.922	p=.378
For female participants: Are you pregnant?	Y: 0 N: 12	Y: 0 N: 19	$X^2(1) = 1.105$	p=.293
For female participants: Do you currently use birth control?	Y: 5 N: 7	Y: 14 N: 5	$X^2(1) = 5.460$	p=.065
For female participants: Do you experience irregular periods?	Y: 5 N: 7	Y: 8 N: 11	$X^2(1) = 2.441$	p=.295
Have you experienced an acute illness or injury in the last two weeks?	Y: 8 N: 20	Y: 9 N: 21	$X^2(1) = .014$	p=.905

*p<.05
**p<.01

Table 4. Summary of group characteristics for musicians and non-musicians.

		PSS	Cortisol T0	Cortisol T30	Cortisol T60	Cortisol T90
PSS	r	1	-.069	-.138	-.164	-.018
	p		.652	.368	.281	.906
Cortisol T0	r	-.069	1	.447	.320	.418
	p	.652		.002	.032	.005
Cortisol T30	r	-.138	.447	1	.810	.744
	p	.368	.002		.000	.000
Cortisol T60	r	-.164	.320	.810	1	.932
	p	.281	.032	.000		.000
Cortisol T90	r	-.018	.418	.744	.932	1
	p	.906	.005	.000	.000	

Table 5. Correlations between scores on the Perceived Stress Scale (PSS) and cortisol concentrations at each timepoint.

		BDI	Cortisol T0	Cortisol T30	Cortisol T60	Cortisol T90
BDI	r	1	-.169	-.191	-.141	-.064
	p		.266	.209	.355	.682
Cortisol T0	r	-.169	1	.447	.320	.418
	p	.266		.002	.032	.005
Cortisol T30	r	-.191	.447	1	.810	.744
	p	.209	.002		.000	.000
Cortisol T60	r	-.141	.320	.810	1	.932
	p	.355	.032	.000		.000
Cortisol T90	r	-.064	.418	.744	.932	1
	p	.682	.005	.000	.000	

Table 6. Correlations between scores on the Beck Depression Inventory (BDI) and cortisol concentrations at each timepoint.

Cortisol

GEE was used to test group differences in salivary cortisol over time. Due to errors in the saliva assay procedure, cortisol concentrations from eleven participants (4 musicians, 7 non-musicians) were inconclusive. Therefore, cortisol analyses were conducted with a final sample size of 47 participants. Analyses were run separately for unadjusted cortisol concentrations (ng/mL), and cortisol concentrations adjusted for total protein (ng of cortisol/mg of total protein). Having been diagnosed with a mental disorder was included as a covariate in all cortisol analyses.

GEE revealed a significant main effect of Time on unadjusted cortisol concentrations (Wald X^2 (3, N=44)=142.237, p<.001). There was no main effect of Group (Wald X^2(1, N=44)=.040, p=.842) and no Group x Time interaction (Wald X^2 (3, N=44)=1.660, p=.646) for unadjusted cortisol. *Aposteriori* comparisons for Time were conducted using the sequential Bonferroni correction for multiple comparisons. Pairwise comparisons showed significant differences between the following pairs of timepoints: Time 0 and Time 30 (p=.014), Time 0 and Time 60 (p=.014), Time 30 and Time 90 (p<.001), and Time 60 and Time 90 (p<.001).

When cortisol was adjusted for total protein, GEE revealed a significant main effect of Time (Wald X^2 (3, N=44)=105.219, p<.001), but not Group (Wald X^2 (1, N=44) <.001, p=.984). There was also no Group x Time interaction (Wald X^2(3, N=44)=.669, p=.881). Pairwise comparisons showed significant differences between: Time 0 and Time 30 (p=.005), Time 30 and Time 60 (p<.001), and Time 60 and Time 90 (p<.001). Unadjusted cortisol and cortisol adjusted for total protein are represented on Figure 13.
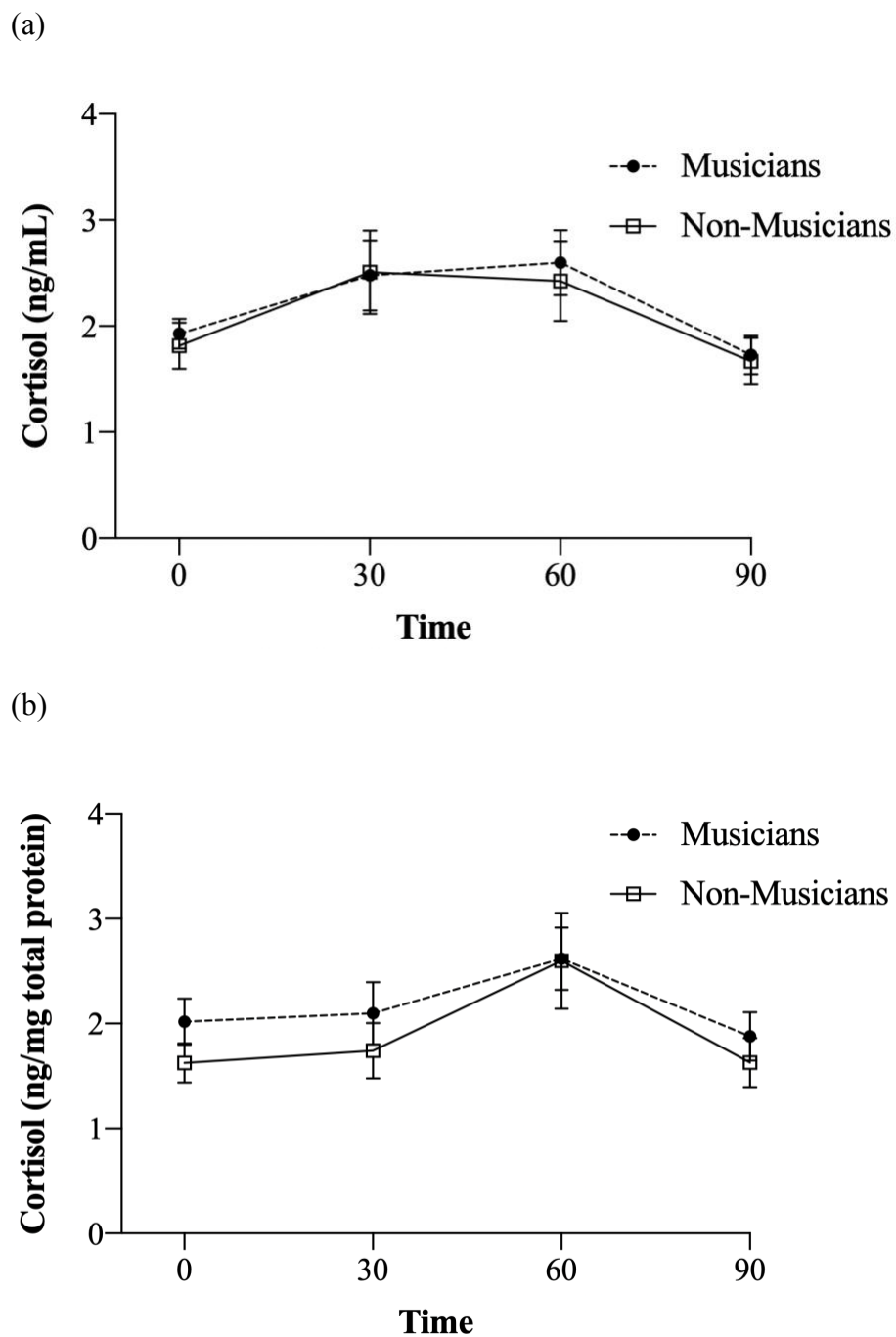
(a)

(b)

Figure 13. Cortisol concentrations by group, unadjusted (a) and adjusted (b) for total protein.

Total Sympathetic Activation, Perceived Acute Stress, and Total Protein

GEE was used to test for group differences in heart rate, systolic blood pressure, and diastolic blood pressure over time. There was a main effect of Time for each sympathetic measure (heart rate: Wald X^2(3, N=58)=34.332, p<.001; systolic: Wald X^2(3, N=57)=21.293, p<.001; diastolic: Wald X^2(3, N=57)=9.793, p=.020). There were no main effects of Group on measures of sympathetic activation (heart rate: Wald X^2(1, N=58)=.712, p=.399; systolic: Wald X^2(1, N=57)=2.443, p=.118; diastolic: Wald X^2(1, N=57)=1.940, p=.164), nor were there any significant Group x Time interactions (heart rate: Wald X^2(3, N=58)=2.879, p=.411; systolic: Wald X^2(3, N=57)=1.619, p=.655; diastolic: Wald X^2(3, N=57)=1.207, p=.751) (see Figure 14 for heart rate, Figure 15 for systolic and diastolic blood pressure).

Perceived acute stress, indicated by scores on the state section of the STAI, was also analyzed for group differences over time using GEE. There was a main effect of Time (Wald X^2(3, N=58)=88.795, p<.001), no main effect of Group (Wald X^2(1, N=58)=.912, p=.340) or Group x Time interaction (Wald X^2(3, N=58)=3.031, p=.387) (see Figure 16).

Finally, GEE revealed a main effect of Time (Wald X^2(3, N=56)=51.220, p<.001) on total protein concentrations. There was no main effect of Group (Wald X^2(1, N=56)=3.117, p=.077) or Group x Time interaction (Wald X^2(3, N=56)=3.119, p=.374) on total protein (see Figure 17).
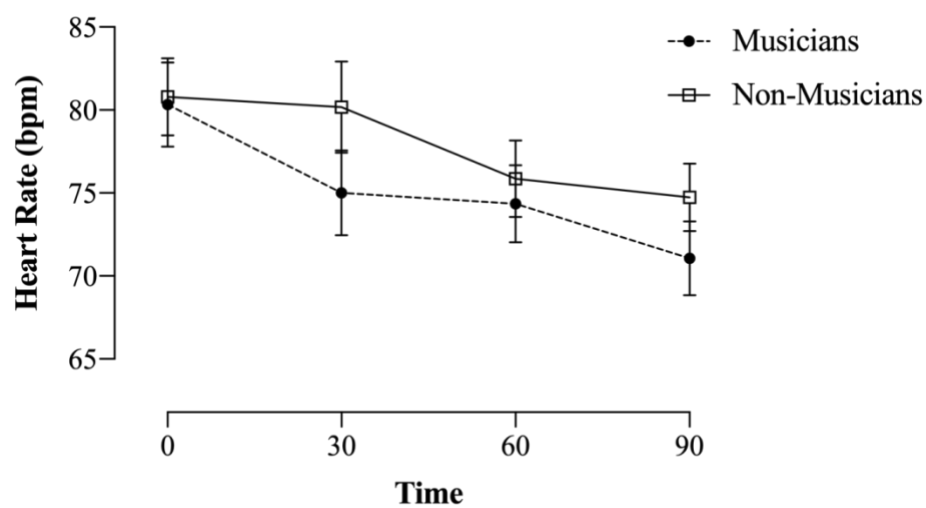
Figure 14. Heart rate in beats per minute (bpm), shown over time between musicians and non-musicians.
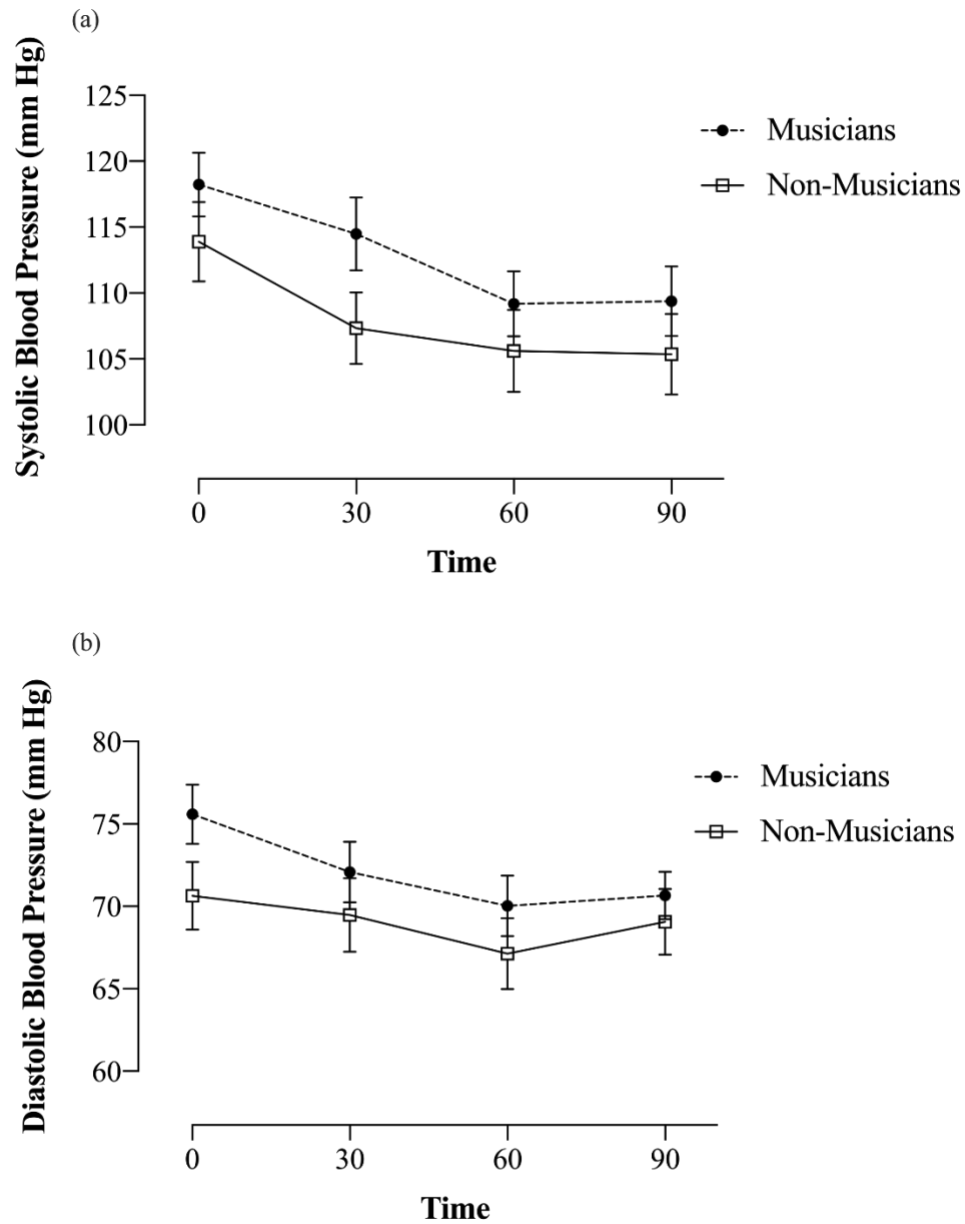
Figure 15. Systolic (a) and diastolic (b) blood pressure in millimeters of mercury (mm

Hg), shown over time between musicians and non-musicians.
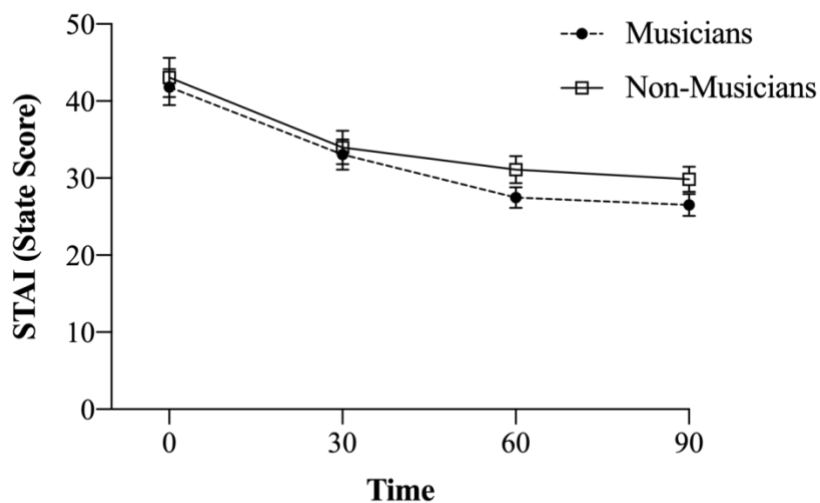
Figure 16. State anxiety scores from the State-Trait Anxiety Index (STAI), shown over time between musicians and non-musicians.
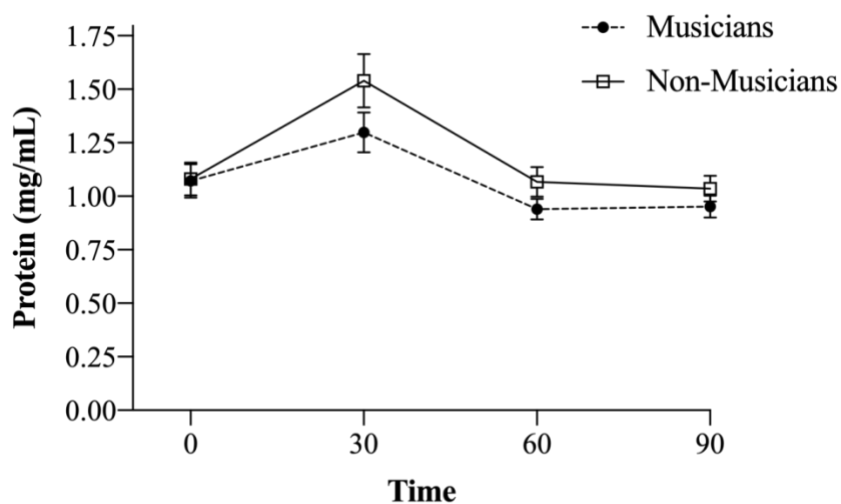
Figure 17. Total protein concentrations in milligrams per milliliter of saliva, shown over time between musicians and non-musicians.

4.4 Discussion

The current study compared physiological self-regulation, measured via acute stress reactivity and recovery, and emotional self-regulation, measured via perceived chronic stress and mental health outcomes in musicians and non-musicians. Musicians showed lower levels of perceived chronic stress and depressive symptoms, and were less likely to have been diagnosed with a mental disorder when compared with non-musicians. The Trier Social Stress Test (TSST) appeared to elicit an acute stress response across groups, as there was a significant overall increase in cortisol concentrations immediately after the TSST. Importantly, the overall effect of time on cortisol levels varied depending on whether cortisol was adjusted for total salivary protein. There were no differences in cortisol reactivity between musicians and non-musicians, whether or not cortisol concentrations were adjusted for total protein.

While there were no differences in acute stress markers between musicians and non-musicians, musicians reported lower levels of perceived chronic stress and depressive symptomology, and were less likely to have been diagnosed with a mental disorder than non-musicians. This finding contrasts with previous reports of higher psychological distress, anxiety, depression (Wesseldjik et al 2019; Vaag et al., 2016), and perceived stress (Bonda et al., 2018) in professional musicians. Professional musicians have also reported lower levels of social support, job satisfaction, and emotional regulation (Holst et al., 2012). The difference between these and the current findings may highlight psychoemotional differences between effects of playing music professionally and playing at an amateur level. Professional musicians continually face

job-related stressors such as financial instability, and little to no benefits, paid time off, or job security. Participants in the present study were young, full-time students who could afford tuition at an expensive private university. They likely participate in musical activities due to intrinsic motivators, since they do not rely on music as a way to earn a living. Professional musicians, on the other hand, face more extrinsic motivators to play frequently and at a high level. These external pressures may lead to poorer emotional self-regulation and more negative mental health outcomes over time. Conversely, engaging in musical experience without the stressors associated with professional musicianship might facilitate *better* mental health outcomes as a challenging, stimulating, and joyful supplement to one's daily life.

When considering the physiological markers of acute stress examined in this study, significant differences in cortisol concentrations over time indicate that the TSST was effective in eliciting an acute stress response. Izawa et al (2013) established that salivary cortisol peaks between 0 and 20 minutes after completing the TSST. However, Izawa et al (2013) did not adjust cortisol concentrations for total protein concentrations. The present findings suggest that the time course of salivary cortisol may be significantly altered depending on whether measured concentrations are adjusted for total salivary protein. When cortisol was adjusted for total protein, a clear peak emerged at timepoint 60. In *aposteriori* comparisons, adjusted cortisol levels at timepoint 60 were significantly higher than timepoint 30. In unadjusted cortisol, concentrations at timepoint 30 and timepoint 60 were roughly equivalent, and did not differ significantly in *aposteriori* comparisons. If only unadjusted cortisol was considered, these results would indicate a cortisol peak at timepoint 30 that is sustained for at least 30 minutes. However, total

salivary protein levels peaked at timepoint 30 (see Figure 17), and when cortisol is adjusted for protein concentrations, there is no peak at timepoint 30. Thus, the unadjusted cortisol peak at timepoint 30 may be indicative of an overall increase in salivary protein release, not specifically cortisol. Other studies reporting on salivary markers have found that total salivary protein concentrations increase in response to acute psychological stress (Naumova et al., 2012; Naumova et al., 2014). In addition, activation of the sympathetic nervous system increases exocytosis from salivary cells, while inhibition of parasympathetic activation evokes most of the salivary fluid excretion (Proctor & Carpenter, 2007). Taken together, the initial peak observed in unadjusted cortisol may be attributable to an overall increase in salivary protein release due to sympathetic activation and parasympathetic inhibition. In contrast to previous findings (Izawa et al., 2013), this suggests that a specific increase in salivary cortisol may occur closer to timepoint 60, or one hour after the onset of the TSST.

Despite these differences in the time course of cortisol depending on total protein, the current study does not provide evidence that musicians and non-musicians differ in acute cortisol reactivity or recovery. While this contrasts with previous investigations of acute stress in musicians (Laohawattanakun et al., 2011; Killough et al., 2016), no studies have systematically evaluated how different types of musical experience may lead to different results. For instance, in the current study, musician participants were recruited from the Tulane University Marching Band. Participation in a marching band is a more anonymous performance experience, with less pressure on the individual to perform well than when performing solo. Perhaps, then, marching band performances do not elicit a robust acute stress response, and would not require any more practice at regulating the

stress response than an average person might experience. A concert pianist or an orchestral soloist may experience more individual performance pressure than one performing in a large ensemble. This type of pressure may elicit a more robust stress response, and the performer would therefore need to self-regulate their physiological response to acute stress more frequently. So, whereas the musicians in the current sample do not show an advantage in this self-regulatory ability, musicians who are more practiced at regulating acute stress reactivity might. However, this claim has not been investigated empirically. Future studies should systematically compare solo performers, ensemble performers, and non-musicians on acute stress reactivity and recovery.

An alternative explanation for why no cortisol differences were observed in the current study may lay in the amount of time passed between each saliva collection. Due to practical constraints, four timepoints were analyzed with thirty minutes between each timepoint. Both adjusted and unadjusted cortisol showed a peak after the onset of the stressor, and both representations of cortisol had values that fell below their initial baseline measurement by the final timepoint (90). This shows that the stressor was effective, and that participants were given enough time to recover. What is limited, however, is an understanding of what happened in between each timepoint. Previous reports have shown meaningful changes in salivary cortisol levels in time windows as narrow as ten minutes (Izawa et al., 2013). In the current study, more narrow windows of measurement may have revealed differences between musicians and non-musicians that last for less than thirty minutes. It is also worth noting that heart rate, blood pressure, and perceived acute stress were highest at timepoint 0, immediately before the stressor. This

suggests that participants experienced anticipatory stress before the TSST was introduced, which likely also contributed to ambiguity in the current results.

Taken together, the current study suggests that amateur musicians may have better emotional self-regulation, measured by long-term mental health outcomes, than non-musicians. While the current findings do not provide evidence for differences in physiological self-regulation between musicians and non-musicians, differences in cortisol reactivity and recovery when adjusted for total salivary protein suggest that future studies should report levels of salivary biomarkers in relation to concentrations of total protein.

Chapter V: General Discussion

The aim of the current studies was to investigate relationships between musical experience and cognitive, emotional, and physiological self-regulation. The primary focus was on associations between musical experience and cognitive regulation, measured by executive functions. Continued enrollment in music programming during childhood was associated with enhanced working memory maintenance and updating (Chapter II), and musical experience in early adulthood was associated with enhanced planning and problem-solving abilities (Chapter III). Among musically experienced adults, the ability to create a four-part harmonization was also associated with planning and problem-solving (Chapter III). With regard to emotional self-regulation, continued enrollment in music programming was associated with higher regulatory self-efficacy in children (II), and musically trained adults demonstrated lower incidences of mental illness, depressive symptoms, and perceived chronic stress (Chapter IV). From a physiological perspective, there was no evidence for a relationship between musical experience and acute physiological stress reactivity or recovery (Chapter IV).

When viewing self-regulation from a cognitive perspective, the current findings provide preliminary support for the idea that cognitive processes influenced by musical experience vary with the context of musical engagement. In Chapter II, more years of enrollment in The Roots of Music was associated with more categories achieved on the Berg card sort task. This observation occurred in the absence of a difference in

perseveration, which suggests that the benefit was due to working memory maintenance and updating rather than set shifting. In Chapter III, there was a relationship between harmonization skill and performance on the Tower of London task, which requires integration of the three core components of executive functions. One possible explanation for the difference in these findings may stem from differences in the cognitive demands of each sample's musical experience. In Chapter II, the type of musical experience being studied was participation in a large community marching band. Marching band music tends to be simple and repetitive, and performed from memory. Harmonization, on the other hand, is complex, intricate, and creative. From a cognitive standpoint, the demands of marching band music would require less integration of cognitive processes, whereas harmonization would require more higher-order engagement and integration of executive functions (Diamond, 2013; Lunt et al., 2012; Collins & Koechlin, 2012). Therefore, marching band programming may influence updating and maintenance processes, but not extend to higher-order functions, like planning or problem-solving. Harmonization, on the other hand, may have led to improvements in the integration of multiple components for more complex functions, but not to improvements on tasks that rely on fewer components. When theoretically considered in the context of how components of executive function relate to one another, these findings suggest that experiences which engage particular components may selectively enhance those components. Experiences that require integration of multiple components, however, may lead to enhanced cognitive integration, rather than global improvements across the components required for the task.

Another possible explanation for the cognitive results reported here is differences in the developmental stage of participants studied in Chapters II and III. Working memory develops before higher-order executive functions like planning and problem-solving (Diamond, 2013), and is supported by intact inhibitory control, which is required to suppress task-irrelevant information (Hasher & Zacks, 1988; Hasher & Zacks, 2006). Working memory maintenance differentiates from inhibition around age ten (Shing et al, 2010). Thus, there may have been an improvement in memory maintenance and updating in school-aged children because that is when the processes involved were most vulnerable to experience-dependent changes, whereas others like problem-solving and planning have yet to fully develop. Because the data from adult participants were correlational and do not include descriptions of their childhood musical experiences, similar conclusions cannot be drawn for the adult group. It is important to note, however, that further investigation is needed before drawing causal conclusions. Future studies should investigate participants of different ages to different types of music training, and systematically measure whether certain types of music training are selectively related to different cognitive outcomes depending on when in development they are experienced.

With respect to emotional self-regulation, the current work provides evidence for enhanced regulatory self-efficacy in musically trained children (Chapter II), and lower incidences of mental disorders, chronic stress, and depressive symptoms in musically trained adults (Chapter IV). These findings align with previous reports that regulatory self-efficacy can predict the likelihood of depression in adolescents (Caprara et al., 2010), and is negatively associated with depressive symptoms in young adults (Zeng et al., 2018). These findings also suggest that regulatory self-efficacy, enhanced by childhood

music training, can buffer against negative mental health outcomes that might emerge in adulthood. This idea, however, does not align with reports of higher prevalence of depression, stress, and anxiety in adult musicians (Vaag et al., 2016; Holst et al., 2012). In continuing with the idea that the context of one's musical experience may selectively impact outcomes, it is worth noting that both child and adult participants that demonstrated emotional benefits of musical experience were members of large marching bands. Participation in a marching band is a uniquely social experience, with members belonging to and bonding with their respective section, while identifying as part of a larger group as well. Evolutionary psychologists have argued that largescale group music making may serve as an evolutionary adaptation to facilitate social bonding and cohesion (Dunbar et al., 2012; Huron, 2003; Tarr et al., 2014). Indeed, group music making has been shown to stimulate an endorphin response similar to that seen during grooming in non-human primates (Keverne et al., 1989; Dunbar et al., 2012), and increases in social closeness are greater when music is made in large groups when compared with small groups (Weinstein et al., 2016). Since perceived social support is closely related to stress and depression (Lin & Dean, 1984; Harandi et al., 2017), perhaps the observed benefits in emotional regulation are due, at least in part, to the social benefits of large-scale group music-making. Future studies should systematically compare mental health outcomes in musicians who play in large groups, musicians who play in small groups, musicians who play solo, and non-musicians.

The current studies did not yield any support for music-related enhancements in physiological self-regulation. While Chapter IV revealed no group difference in cortisol reactivity over time in response to an acute stressor, self-reported chronic stress levels

were lower in musicians than non-musicians. It is therefore possible that physiological

markers of chronic, rather than acute, stress may differ between musicians and non-

musicians. This possibility remains plausible despite the fact that there was not a

baseline group difference in cortisol concentrations. Because cortisol undergoes major

fluctuations throughout the day, a single timepoint measurement of cortisol in serum,

urine or, in our case, saliva is not likely to provide reliable insight on long-term changes

to the cortisol system (Russell et al., 2012). Future investigations of physiological

changes under chronic stress may turn to markers that provide information on systemic

cortisol exposure over time, such as hair (Russell et al., 2012; Cirimele et al., 2000).

Overall, the current studies provide evidence for cognitive and emotional benefits

of musical experience to self-regulation. Although the studies presented do not warrant

causal claims for music-dependent enhancements, the observed differences provide

promising avenues for future experimental studies. In sum, the relationship between

musical experience and different domains of self-regulation may depend heavily on

musical context, the developmental stage in which one engages with music, and how the

two interact.

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Biography

Jenna Lauren Winston graduated from Tulane University in 2014 with a Bachelor of Fine Arts in Vocal Performance, and a Bachelor of Science in Psychology. She received magna cum laude honors and departmental honors in Music upon graduation. As a lifelong musician, she has been interested in the relationship between music and psychology since she was a child. During her undergraduate studies, no Tulane program existed that combined her two interests, and so she studied them separately. In 2015, she decided to pursue a Master's of Neuroscience at Tulane, which is when she met Dr. Paul Colombo and learned of his interest in music and neuroplasticity. Upon Dr. Colombo's recommendation, she entered the Psychological Science doctoral program in 2016 and was one of two founding members of a lab dedicated to studying music and neuroplasticity.

In addition to her research interests, Jenna has always been committed to the education of young people. She has taught multiple undergraduate courses, and has mentored several undergraduate researchers in her time at Tulane. In addition to teaching in higher education, Jenna has consistently taught musical theatre and voice to children and adults throughout her graduate and undergraduate careers. She has remained committed to performing, most often with her touring band Miss Mojo. She has also appeared in six Summer Lyric Theatre productions during her time at Tulane. Jenna hopes to continue singing, teaching, and learning in New Orleans for many years to come.