

Electronic Thesis and Dissertation Repository

---

December 2014

# Creativity as a Mental State: An EEG Study of Musical Improvisation

Joel A. Lopata

*The University of Western Ontario*

Supervisor

Dr. Elizabeth Nowicki

*The University of Western Ontario*

Graduate Program in Education

A thesis submitted in partial fulfillment of the requirements for the degree in Doctor of Philosophy

© Joel A. Lopata 2014

Follow this and additional works at: <https://ir.lib.uwo.ca/etd>

 Part of the [Educational Psychology Commons](#)

---

## Recommended Citation

Lopata, Joel A., "Creativity as a Mental State: An EEG Study of Musical Improvisation" (2014). *Electronic Thesis and Dissertation Repository*. 2552.

<https://ir.lib.uwo.ca/etd/2552>

This Dissertation/Thesis is brought to you for free and open access by Scholarship@Western. It has been accepted for inclusion in Electronic Thesis and Dissertation Repository by an authorized administrator of Scholarship@Western. For more information, please contact [tadam@uwo.ca](mailto:tadam@uwo.ca).

CREATIVITY AS A MENTAL STATE: AN EEG STUDY OF MUSICAL  
IMPROVISATION

(Thesis format: Monograph)

by

Joel Alan Lopata

Graduate Program in Educational Studies

A thesis submitted in partial fulfillment  
of the requirements for the degree of  
Doctor of Philosophy

The School of Graduate and Postdoctoral Studies  
The University of Western Ontario  
London, Ontario, Canada

© Joel A. Lopata 2014

## **ABSTRACT**

Researchers in cognitive neuroscience have used brain-imaging methods (e.g., EEG, fMRI) to investigate the neural correlates of creative cognition and have found increased activity in the alpha frequency band (Fink et al., 2009a, 2009b; Martindale, 1975), however few studies have used neuroscientific measures to investigate artistic creativity. Such studies are valuable because they share a characteristic of ecological validity. In this study I used EEG, the Alternate Uses Test (Guilford, 1967), and the Consensual Assessment Technique (Amabile, 1982) to substantiate a conceptualization of creativity as a mental state characterized by a distinct pattern of neural activity. The participants were musicians with and without previous formal institutional training in improvisation. Amongst those with previous training, frontal upper alpha synchronization in the right hemisphere was greater when musicians improvised than when they played back and listened to melodies. Originality scores correlated with frontal upper alpha synchronization in the right hemisphere during improvisation, and frontal upper alpha synchronization in the right hemisphere correlated with expert ratings of created products. The relationship of frontal upper alpha synchronization in the right hemisphere during improvisation and the quality of created products was mediated by aptitude for originality. This suggests that training acts as a pathway for the development of creative gifts into creative talents observable in the quality of created products.

### **Keywords**

EEG; Alpha; Frontal Cortex; Creativity; Originality; Divergent Thinking; Innovation; Improvisation; Music; Aptitude; Training.

## **DEDICATION**

This dissertation is dedicated to my mother Chava who provided immense support and infused a love of teaching and learning, my father Abraham who shared his love and his love of music, my brother Ron who elicited my love of the piano and who introduced me to jazz music, Paul Farkas who shared his excitement for innovative thinking, and my nephew Jacob and niece Evie who inspired me to care for the education of future generations.

## ACKNOWLEDGMENTS

I am very grateful to my supervisor Dr. Elizabeth Nowicki for her immense and continued guidance, supervision, support, and confidence throughout the duration of this project, to Dr. Marc Joanisse for his guidance and for welcoming me to conduct research in his EEG lab, and to Dr. Carol Beynon for her assistance and suggestions at key points along this journey. I also am appreciative of Dean Vicki Schwean, Dr. Jacqueline Specht, and Dr. Stephen Bird for their support and enthusiasm for my progress and this research. Thank you to my colleagues Adrienne Sauder for assistance in editing and formatting and Jo Ann Iantosca for assistance with inter-rater reliability measures.

I thank all the wonderful musicians for contributing as participants and as adjudicators. I also thank Miles Davis, Thelonious Monk, John Coltrane, Keith Jarrett, Duke Ellington, and countless other legends of improvisation for their inspirational voices in music.

## TABLE OF CONTENTS

<b>ABSTRACT</b> .....	ii
<b>DEDICATION</b> .....	iii
<b>ACKNOWLEDGMENTS</b> .....	iv
<b>TABLE OF CONTENTS</b> .....	v
<b>LIST OF TABLES</b> .....	vii
<b>LIST OF FIGURES</b> .....	viii
<b>LIST OF APPENDICES</b> .....	ix
<b>CHAPTER 1: Introduction</b> .....	1
<b>Organization of the Study</b> .....	4
<b>Literature Review</b> .....	5
<b>Concepts of Creativity - Localizing the Construct</b> .....	5
<b>Hierarchy of Consciousness</b> .....	10
<b>Electroencephalography</b> .....	14
<b>Alpha Activity during Creative Cognition</b> .....	15
<b>Interpretations of Alpha Activity During Creative Cognition</b> .....	20
<b>Heritability of Creativity</b> .....	22
<b>Creativity as an Emergent Phenomenon</b> .....	24
<b>Gagné’s Theory of Talent Development</b> .....	27
<b>Artists’ Experience of Creativity</b> .....	29
<b>Studies of Artistic Creativity</b> .....	32
<b>Assessment of Creativity</b> .....	35
<b>Summary</b> .....	42
<b>Aims, Research Questions, and Hypotheses</b> .....	45
<b>CHAPTER 2: Method</b> .....	51

<b>Recruitment</b> .....	51
<b>Participants</b> .....	51
<b>Measures</b> .....	54
<b>Procedure</b> .....	55
<b>EEG Procedures</b> .....	59
<b>CHAPTER 3: Results</b> .....	63
<b>Demographic Differences between Groups</b> .....	64
<b>Reliability of Measures</b> .....	64
<b>Electroencephalogram (EEG)</b> .....	68
<b>Alternate Uses Test (AUT)</b> .....	76
<b>Musical Improvisation Performance Questionnaire (MIPQ)</b> .....	80
<b>Partial Correlations</b> .....	84
<b>CHAPTER 4: Discussion</b> .....	88
<b>EEG</b> .....	88
<b>Alternate Uses Test</b> .....	92
<b>Musical Improvisation Performance Questionnaire</b> .....	96
<b>Partial Correlation</b> .....	100
<b>Implications of the Current Study</b> .....	101
<b>Limitations</b> .....	107
<b>CHAPTER 5: Summary and Conclusions</b> .....	113
<b>REFERENCES</b> .....	117
<b>CURRICULUM VITAE</b> .....	152

## LIST OF TABLES

Table 1. Inter-rater Correlations of Mean Subscale Scores of the Music Improvisation Performance Questionnaire by Adjudicator.....	66
Table 2. Inter-rater Correlations of Mean Subscale Totals and Mean Measure Totals of the Music Improvisation Performance Questionnaire by Adjudicator.....	67
Table 3. Means and Standard Deviations for Frontal High Alpha Synchronization in Left and Right Hemispheres by Training Groups.....	73
Table 4. Non-FITI Group (n=12) Correlations between Frontal High Alpha Synchronization in Left and Right Hemispheres, by Experimental Task.....	75
Table 5. FITI Group (n=10) Correlations between Frontal High Alpha Synchronization in Left and Right Hemispheres, by Experimental Task.....	75
Table 6. Non-FITI Group (n=12) Correlations of Frontal High Alpha Synchronization During Music Tasks with Age, Music Experience, and Improvisation Experience, by Cortical Hemisphere.....	77
Table 7. FITI Group (n=10) Correlations of Frontal High Alpha Synchronization During Music Tasks with Age, Music Experience, and Improvisation Experience, by Cortical Hemisphere.....	77
Table 8. Non-FITI Group (n = 12) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, and Frontal High Alpha Synchronization in the Right Hemisphere during Listen, Playback, and Improvisation Tasks.....	79
Table 9. FITI Group (n = 10) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, and Frontal High Alpha Synchronization in the Right Hemisphere during Listen, Playback, and Improvisation Tasks.....	79
Table 10. Means and Standard deviations for Subscales, Subscale Total, and Full Total of the Musical Improvisation Performance Questionnaire.....	81
Table 11. Non-FITI Group (n = 12) Correlations between the Musical Improvisation Performance Questionnaire Subscales, Subscale Total, and Full Total and Frontal High Alpha Synchronization in the Right Hemisphere during Music Experiment Tasks.....	83
Table 12. FITI Group (n = 10) Correlations between the Musical Improvisation Performance Questionnaire Subscales, Subscale Total, and Full Total and Frontal High Alpha Synchronization in the Right Hemisphere during Music Experiment Tasks.....	83
Table 13. Non-FITI Group (n = 12) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, Musical Improvisation Performance Questionnaire Subscales, and Musical Improvisation Performance Questionnaire Totals.....	85



## LIST OF FIGURES

Figure 1. Frontal Upper Alpha Synchronization During Music Tasks in the Non-FITI Group.....	70
Figure 2. Frontal Upper Alpha Synchronization During Music Tasks in the FITI Group.....	70

## LIST OF APPENDICES

Appendix A: Ethics Approval Form.....	137
Appendix B: Recruitment Poster.....	138
Appendix C: Letter of Information.....	139
Appendix D: Musical Improvisation Performance Questionnaire (MIPQ).....	141
Appendix E: Participant Information Questionnaire. ....	142
Appendix F: Alternate Uses Test item images. ....	144
Appendix G: Music Charts.....	148
Appendix H: Debriefing Form.....	151

## CHAPTER 1: Introduction

Researchers in cognitive neuroscience have used brain-imaging methods (e.g., EEG, fMRI) to investigate the neural correlates of creative cognition and have found increased activity in the alpha frequency band (Fink et al., 2009a, 2009b; Martindale, 1975; Martindale & Hasenpus, 1978). Dietrich (2004a) interpreted this pattern of neural activity as evidence of a spontaneous processing mode occurring while people are engaged in the intuitive processing of thoughts and ideas from the temporal, occipital, and parietal lobes into the working memory buffer in the frontal brain area (i.e., prefrontal cortex). Although initially interpreted as cortical idling, recent research has shown that increased frontal alpha activity is related to top-down processing, internal focus of attention, and sensory inhibition (Buzsaki & Draguhn, 2004; Klimesch et al., 2007; Ward, 2003). These processes are reminiscent of improvising artists' descriptions of the creative process (Berkowitz, 2007; Berliner, 1994; Nardone, 1997). Improvising artists specifically have described a dissolution of self, an intuitive mental state, and a fluctuation between intuitive and analytic mental states (Nelson & Rawlings, 2007).

Few studies have used neuroscientific measures to investigate studies of artistic creativity. Such studies are valuable though because they share a characteristic of ecological validity. Past research on artistic creativity has indicated that the frontal brain areas may play a special role in creative cognition, however some researchers have found increased alpha activity (Fink, Graif, & Neubauer, 2009) and some decreased alpha activity (Petsche, 2002, 2005; Petsche et al., 1997). These opposing findings may be due to the measurement of different types of creativity with some types relying on prefrontal engagement and some disengagement (Dietrich & Kanso, 2010). As such, it is necessary

to delineate types of creativity and to measure frontal activity during tasks that facilitate the cognitive processing modes specific to these individual *subcreativities*.

In the current study, I developed an experiential state-based conceptualization of creativity that is hallmarked by the spontaneous processing of intuitive thoughts and the expression of these through a medium in real time. In brief, I conceptualized creativity as a distinct mental state involving improvisation. The skill of improvisation crosses domain boundaries, and is necessary in any field that incorporates adaptation, problem solving, and innovation (Limb & Braun, 2008). As a student and teacher, I have noticed a lack of opportunity for learners to enter into creative mental states, as well as a lack of support and guidance once engaged. It is my belief that the facilitation of such mental states would lead to increased creativity and innovation, especially in learners with aptitudes for creativity. However, it is first essential to investigate whether there is neuroscientific evidence that such a creative mental state exists.

In this study I used EEG, the Alternate Uses Test (Guilford, 1967), and the Consensual Assessment Technique (Amabile, 1982) to substantiate a conceptualization of creativity as a mental state characterized by a distinct pattern of neural activity. Further along in this dissertation, EEG is described in more detail in its own section and the Alternate Uses Test and the Consensual Assessment Technique are described in detail in a section on the assessment of creativity.

More specifically, the primary aim of this study was to use EEG to investigate whether frontal brain wave changes occurring during spontaneous musical creativity are different than during non-spontaneous (i.e., deliberate) musical creativity. Framing this aim as a research question, I asked: Does frontal alpha activity correspond to the degree

of creativity of different musical tasks? Differences in brain activity occurring during time intervals of spontaneous musical creativity would support my experiential conceptualization of creativity. This conceptualization is outlined in a later section on conceptualizations of creativity. Further, I aimed to investigate the above differences in neural activity (i.e., frontal alpha synchronization) in participants with training in creativity and participants without training in creativity.

The second aim of this study was to use EEG and the Alternate Uses Test (Guilford, 1967), a measure of divergent thinking, to investigate the relationship between frontal alpha activity during music tasks of varying creativity demands (i.e., improvisation, deliberate playing, and listening) and aptitudes for divergent thinking and originality. Framed as a research question, I asked: Do aptitudes for divergent thinking and originality correlate with frontal alpha activity during tasks of varying creativity demands?

The third aim of this study was to use EEG and the Consensual Assessment Technique (Amabile, 1982) to investigate whether alpha activity during spontaneous musical composition predicts the quality of an individual's improvised musical performances as rated by domain experts. Framed as a research question, I asked: Does alpha band activity during spontaneous composition predict improvised performance quality? I also aimed to investigate whether this predictive relationship would occur in groups with and without formal institutional training in improvisation (FITI).

The fourth aim of this study was to investigate if aptitude for creativity mediates the relationship between frontal alpha activity and improvised performance quality. Specifically, I aimed to investigate whether the relationship between frontal alpha

synchronization during musical improvisation and expert ratings of improvised musical performances persists when controlling for aptitudes for creativity. Therefore, my fourth research question was: Does aptitude for creativity mediate the relationship between frontal alpha synchronization during improvisation and quality of improvised performances as rated by domain experts?

To date, electroencephalogram (EEG) has not been used to measure the neural correlates of spontaneous musical composition (i.e., improvisation) during ecologically valid music tasks.

### **Organization of the Study**

In the first chapter of this dissertation I will follow a line of reasoning that underlies my theory that there is a distinct mental state that can be called *creativity*. I will present (a) various conceptualizations of creativity including my own, (b) previous research on brain-wave changes associated with creative cognition, (c) previous findings on the heritability of creativity (d) Gagne's (1997) theory of talent development (e) artists' descriptions of their experiences of the creative process, and (f) a background on the assessment of creativity. In the second chapter I will discuss the methods and procedure I employed, and in the third chapter I will present the results of the study. In the fourth chapter I will discuss these results and my interpretations of them and will suggest implications of my findings for education, make recommendations for future research, and present the limitations of the study. Finally I will summarize the findings and draw conclusions before sharing my hopes for the pragmatic application of this dissertation.

## Literature Review

### Concepts of Creativity - Localizing the Construct

Early conceptions of creativity were mystical in orientation, with creativity often equated to divinity and seldom differentiated from *genius*; however, over the past half-century creativity has most commonly been referred to as *divergent thinking* or *originality* (Albert & Runco, 1999). Over this period researchers have conceptualized creativity in several ways, defining the construct as a cognitive ability, as a value assigned to products, as novelty accepted within a social system, as a personality dimension, and as a mode of being. In the coming sections I will outline these conceptualizations.

**The cognitive ability orientation.** In a seminal address to the American Psychological Association (APA), J. P. Guilford (1950) suggested that creativity is an aptitude occurring in all humans that is psychometrically measurable and worthy of study (as cited in Sternberg & Lubart, 1999). This suggestion has influenced decades of research on the cognitive abilities underlying creative ideation.

Soon thereafter, Osborn (1953) defined creativity as ideation ability, whereby creativity was quantified by measuring the number of possibilities an individual could generate regarding the uses of a common object (as cited in Sternberg & Lubart, 1999). A number of years later, Paul Torrance (1974) developed the Torrance Tests of Creative Thinking (TTCT). These assessments involved both divergent thinking and problem solving tasks, and was scored for (a) quantity of responses (i.e., fluency), (b) variety of types of responses (i.e., flexibility), (c) rarity of responses (i.e., statistical originality), and (d) amount of detail (i.e., elaboration; Sternberg & Lubart, 1999). Assessments such as

those involved in the Torrance Tests of Creative Thinking aimed at measuring individual cognitive abilities, thereby assigning statistically reliable normative values about an individual's capacity to think in novel and original ways. Originality here is defined as ideas that are substantially unique in comparison to the norm. As such, in the cognitive ability conceptualization of creativity individuals can be labeled as being of low, average, or high creativity. This psychometric perspective can therefore be said to conceptualize "being creative" as a value laden label assigned to an individual based on that person's aptitude for divergent thinking and originality (i.e., inherent creativity). Under this implicit understanding of the way the world is (i.e., ontology), creativity is conceptualized as located within the individual's mind, and as a product of objective, normatively valued cognitive abilities.

**The product orientation.** Some researchers (Amabile, 1983; Sternberg, 1986) objected to the reliance on psychometric measures of creativity in assessing creativity, arguing that these are limited in nature. These researchers advocated for the adjudication of samples of actual creative work by domain experts as essential to the determination of creativity. In accord with these sentiments, MacKinnon (1978) and Runco (1989a) suggested that analysis of the *creative product* is central to the measurement of creativity. Whereas Guilford (1950), Torrance (1974), and their supporters defined creativity as the sum of cognitive abilities residing within an individual, other researchers (Amabile, 1983; Mackinnon, 1978; Runco, 1989a; Taylor, 1960; Treffinger & Poggio, 1972; Wallach, 1976) broadened this definition to include artifacts (i.e., evidence of creativity). This second wave of researchers located creativity as embedded in the creative product. Although both the cognitive ability and product orientations define, locate, and measure



creativity differently, they are commensurable in that their concepts share the implicit notion of creativity as an assigned social value.

**The systems approach.** Csikszentmihalyi's (1988) systems approach to creativity elaborated the product orientation to creativity by delineating the features responsible for the acceptance or rejection of a *creative* idea or product within a bound social system. He offered distinct definitions of terms such as the *domain* and the *field* and in doing so explained the roles of culture and society as they affect creativity.

Csikszentmihalyi (1999) defined a field as the group of individuals that compose a domain. These individuals collectively act as gatekeepers who decide upon whether a new idea or product will be accepted in a specific area of study: a domain.

Csikszentmihalyi's (1999) model is a tri-partite one. Along with the (a) cultural and (b) societal, he also included (c) intra-personal factors (i.e., factors located within an individual's psychological make-up) in pre-disposing individuals towards having their products or ideas accepted in a domain (Csikszentmihalyi, 1999).

**Experiential orientations.** The most well known experiential conceptualization of creativity is Csikszentmihalyi's (1996) concept of *flow*. My own personal definition of creativity is also an experiential state-based one, as I conceptualize creativity as a unique mental state characterized by a distinct cognitive processing mode (i.e., spontaneous processing). Although there are some similarities between Csikszentmihalyi's definition and my own, there are also notable differences. Before comparing the two concepts, I will describe the features of both.

**Csikszentmihalyi's flow theory.** Csikszentmihalyi (1996) gave the name flow to the sensation workers in a variety of domains have described as enjoyable ease while

engaging in performing a task. He conceptualized creativity and flow as two separate phenomena, defining creativity as the creation of novelty, and flow as the mental state wherein individuals experience “an almost automatic, effortless, yet highly focused state of consciousness” (Csikszentmihalyi, 1996, p. 110). According to his theory, any task can be an opportunity for flow if the parameters for flow are followed or are present.

***My experiential state-based concept of creativity.*** I conceptualize creativity as a distinct mental state that includes (a) engagement in an activity, (b) spontaneous processing of thoughts, and (c) the expression of these thoughts through a medium (e.g., voice, a writing tool, a musical instrument). For example, during jazz pianist Keith Jarrett’s (1975) Koln concert, Jarrett was engaged in playing piano, spontaneously composing music by channeling a stream of intuitive thoughts, and expressing these thoughts through his piano in real time.

Although I do not wish to deny the validity of any of the previously mentioned conceptualizations of creativity, I would like to use a different one in order to achieve different ends through the current study: to identify the educationally relevant factors that nurture aptitudes for spontaneous creativity. This shift in conceptualization minimizes social value assignment (i.e., labeling) in the definition of creativity and endorses a change in the linguistics of the words *being* and *creative*. In the cognitive ability and product orientations, the word *creative* is an adjective assigned to an individual or product by external sources (i.e., an assessment measure or an adjudicator) whereby an individual or product is described (i.e., labeled) as *creative* or said to “be *creative*”. Conversely, in my proposed state-based orientation *being* is used as a verb and *creative* as an adverb describing the way a person is *being* during a particular interval in time. In

this sense, when a person is engaged in a creative activity that person is being creative, as long as the above-mentioned parameters are involved. Based on the above explanation, it can be stated that during the duration (i.e., time interval) of the Koln concert, Keith Jarrett was being creative.

There are congruencies between Csikszentmihalyi's (1999) concept of flow and my own experiential concept of creativity. For example, both Csikszentmihalyi and I refer to creativity as a distinct mental state. Also, there is evidence of distinct patterns of neural activity occurring in frontal brain regions during both these states (Bengtsson, Csikszentmihalyi, & Ullen, 2007; Dietrich, 2004b). However, there are notable differences between our concepts. First, for Csikszentmihalyi, creativity is a value assigned to a product or person by domain experts, whereas for me, it is a mental state that is separate from the quality of the product being created. Next, Csikszentmihalyi contends that any task can lead to the flow brain state, whereas I argue that tasks relying heavily on logical reasoning and critical analysis are associated with a different mental state (i.e., a deliberate processing mode).

Csikszentmihalyi (1999) and I also define flow differently. For Csikszentmihalyi, flow is the sensation of effortlessness, ease, and focus that can occur when people are engaged in a task, whereas for me, flow is the stream of intuitive thoughts and ideas that emerge spontaneously during engagement in a task. Fundamentally, for Csikszentmihalyi flow is sensation, whereas for me flow is unhindered intuitive cognitive ideation occurring in real time. Our fingers may be pointed towards the same psychological phenomenon, however there are differences in the nuances of our

conceptualizations of this state. I therefore do not approach this study as an investigation of flow.

In the coming sections I will review research on the neural correlates of creativity, and on the cognitive processes underlying creativity.

### **Hierarchy of Consciousness**

Dietrich (2003) conceptualized the brain as being hierarchically ordered. In this conceptualization, different brain areas have different functions, with some being more basic, simple, and fundamental, and others being more complex. From an evolutionary perspective, the brain can be viewed as having been formed from the inside out. It is hypothesized that the innermost structures dealing with unconscious functions fundamental to survival are the oldest and that the outer structures dealing with conscious functions such as thinking, planning, sensing, and acting, have evolved more recently (Passer, Smith, Atkinson, Mitchell, & Muir, 2003). Over time, random genetic mutations gave rise to areas of the brain that increased the probability of survival and thriving. These mutations were passed on becoming part of the species' regular neuroanatomical structure (Passer et al., 2003).

**Anatomy of the brain and the prefrontal cortex.** The human brain can be deconstructed into three main areas: the forebrain, the midbrain, and the hindbrain. The hind and midbrain, including structures such as the cerebellum, pons, and medulla oblongata (as well as a variety of key bundles of neurons called nuclei), are key in unconscious automatic functions related to survival (Carlson, 2007).

When conceptualizing a neuroanatomical hierarchy of consciousness, the anatomically lower (and more medial) brain areas (e.g., brainstem) are placed lower in

the hierarchy, whereas the increasingly integrative and complex functioning regions reside further from the core of the brain, in the higher and more lateral regions (e.g., dorsolateral prefrontal cortex). The more complex of these regions are located in the cerebral cortex, with the prefrontal cortex being the pinnacle higher-order region (Dietrich, 2003).

The lower brain areas will not be discussed further in this dissertation because the higher and more frontal areas have been implicated as being associated with divergent thinking and with spontaneous artistic composition (Bhattacharya & Petsche, 2005; Fink, Graif, & Neubauer, 2009; Limb & Braun, 2008). I will instead focus on the forebrain, and particularly on the prefrontal cortex.

Anterior to the motor association cortex lies the prefrontal cortex. Comprising nearly half of the frontal lobe, the prefrontal cortex is involved in integrating perceptual information, formulating plans and strategies, and instructing the motor cortices to execute actions (Dietrich, 2003). The sum of the processes occurring in the prefrontal cortex is often referred to as executive functioning (Dietrich, 2003).

The prefrontal cortex is functionally divided into two regions: the ventromedial and dorsolateral prefrontal cortices. The ventromedial prefrontal cortex has been associated with social functioning and sense of self. Due to its complex interconnections with the limbic cortex, Damasio (1994) theorized that the ventromedial prefrontal cortex is involved in emotion related learning; he more incisively theorized that the ventromedial prefrontal cortex is involved specifically in the assessment of personal consequences to one's own behaviours. Dietrich (2004a) explained that the ventromedial prefrontal cortex is involved in the manifestation of emotions into consciousness through

the delivery of emotional information from deep limbic structures into working memory. Alternatively, the dorsolateral prefrontal cortex primarily receives innervation from other regions of the cerebral cortex (i.e., temporal, occipital, parietal lobes) and its primary output is towards the motor cortices. As such it is not related to emotion-based learning as is the ventromedial prefrontal cortex, but rather is involved in cognitive functions such as working memory, directed attention, and temporal integration (Fuster, 2000; Goldman-Rakic, 1992; Knight & Grabowecky, 1999; Posner, 1994). Dietrich (2004a) explained that the dorsolateral prefrontal cortex is involved in information processing whereby thoughts emanating from the temporal, occipital, and parietal lobes are rendered into conscious awareness in working memory. The functions of the dorsolateral prefrontal cortex have been implicated in higher order cognitive abilities such as abstract thinking, self-reflective consciousness, and cognitive flexibility. A number of cognitive neuroscientific theorists (Baddeley, 2000; Courtney, Petit, Haxby, & Ungerleider, 1998; Dehaene & Naccache, 2001; Posner, 1994) have thus interpreted that the dorsolateral prefrontal cortex is the site of “full fledged, self-reflective consciousness” (Dietrich, 2003, p. 233).

#### **Deliberate and spontaneous processing modes and the prefrontal cortex.**

Working memory has been conceptualized as the site of consciousness (Courtney et al., 1998; Dehaene & Naccache, 2001; Dietrich, 2004a), however the manner in which information manifests into working memory differs as a function of the cognitive processing mode a person is in. Dietrich (2004a) delineated between two different processing modes occurring during cognitive ideation—a deliberate mode and a spontaneous mode. The deliberate mode can be compared to what has in past literature

been referred to as *analytical* processing, whereas the spontaneous mode can be compared to what has been referred to as *intuitive* processing (Shirley & Langan-Fox, 1996; Simonton, 1975). Instigated by circuits in the prefrontal cortex, deliberate processing tends to yield thoughts that are rational, structured, and conforming to internalized social norms, whereas spontaneous processing tends to yield an intuitive stream of unfiltered, non-conforming thoughts manifested into working memory. In the deliberate processing mode, attention guides the retrieval of information (i.e., semantic memories) stored in long-term memory, whereas in the spontaneous processing mode attention is less active, allowing for intuitive thoughts to surface into conscious awareness. In deliberate processing, the dorsolateral prefrontal cortex is recruited in a search engine-like process, actively retrieving specific information and rendering it in working memory for a transient duration (Cabeza & Nyberg, 2000; Hasegawa, Hayashi, & Miyashita, 1999). The prefrontal cortex instigates this information retrieval process in a circuit wherein cognitive information is retrieved from the temporal, occipital, and parietal lobes (Friedman & Förster, 2002). Conversely, in spontaneous processing the attention system does not actively select the content of working memory but rather it down-regulates. This allows for unguided thoughts to enter the working memory buffer as an intuitive stream of ideas. In other words, during spontaneous processing, when the dorsolateral prefrontal cortex is down-regulated, unpremeditated ideas surface into working memory from the temporal, occipital, and parietal lobes (Dietrich, 2003). As such, the quality of content rendered in working memory differs depending on whether semantic information is retrieved by deliberate processing or whether intuitive thoughts are allowed to emerge into consciousness via spontaneous processing.

The prefrontal cortex has also been implicated in the function of inhibitory control of inappropriate behaviours. Lhermitte (1983) and Lhermitte, Pilon, and Serdaru (1986) found that frontal lobe patients were overly dependent on immediate environmental cues. They lacked the ability to filter environmental triggers and to decide which ones were appropriate to imitate or to act upon. The researchers interpreted that the ventromedial prefrontal cortex is implicated in the filtering of environmental information, and in censoring responses that may be inappropriate or maladaptive. This may be especially relevant to creativity because during spontaneous composition it is important for artists to be able to bypass internal censoring and to express their intuitive stream of thoughts (i.e., internal voice; Dietrich, 2004a).

The spontaneous processing mode can therefore be conceptualized as a distinct mental state characterized by the manifestation of intuitive thoughts in working memory and occurring when the frontal attentional network is disengaged from controlling the content of the working memory buffer.

### **Electroencephalography**

In 1929, Hans Berger discovered EEG when he measured alpha-band activity over the human scalp (Sanei & Chambers, 2007). Since then, the scope and abilities of EEG have been broadened to include the study of different spectral ranges as well as synchrony of cortical and subcortical oscillations occurring at different sites over the scalp. Even with the invention of other more spatially accurate imaging technologies (e.g., fMRI), EEG has retained its usefulness due to its precise temporal accuracy.

The underlying assumption of EEG imaging for cognitive neuroscientific study is that variation in activity in a specific brain region is an indication of task-relevant



recruitment of that specific region (Pfurtscheller & Aranibar, 1977). Post-synaptic potentials in grey matter of the cerebral cortex vary continuously, and it is this variable activity that is recorded at various sites across the scalp by EEG, and then described as amplitude or power values in spectral frequency ranges (i.e., alpha, beta, delta, theta; Rippon, 2006).

Most commonly, EEGs are described in terms of frequency. Spectral analysis is used to identify brain-wave characteristics (i.e., amplitude) by frequency range. These ranges have traditionally been labeled as delta waves (less than 4 Hz), theta waves (4-7 Hz), alpha waves (8-13 Hz), beta waves (14-30 Hz), and gamma waves (30-50 Hz). More recently, frequency ranges have been delineated further with alpha frequencies divided into low alpha (8-10 Hz) and high alpha (11-13 Hz), and beta frequencies into beta 1 (13-16 Hz), beta 2 (16-20 Hz), and beta 3 (20-30 Hz). The alpha and beta ranges are most commonly associated with conscious wakeful activity, with alpha activity associated with relaxed states (i.e., altered states of consciousness, intuitive states), and beta activity associated with logical reasoning (i.e., rational thought, critical analysis; Carlson, 2007).

In the current study, I used EEG to determine if brain-wave changes occurred during spontaneous music composition tasks in comparison to less creatively demanding tasks. Further information on the procedure I used is provided in the method section of this dissertation.

### **Alpha Activity during Creative Cognition**

**Alpha activity during divergent thinking.** The quality of thoughts elicited from the spontaneous and deliberate processing modes differ, with the deliberate mode

yielding more rational and logical thoughts, and the spontaneous mode yielding more intuitive ones. To study these modes empirically, researchers (e.g., Fink, Benedek, Grabner, Staudt, & Neubauer, 2007; Jauk, Benedek, & Neubauer, 2012; Jausovec, 1997; Krug, MÃ¼lle, Dodt, Fehm, & Born, 2003) have contrasted tasks involving divergent and convergent thinking.

Divergent thinking tasks involve open-ended questions and stimuli that have many possible answers, whereas convergent thinking tasks involve questions and stimuli that have only a single correct response. An example of a divergent thinking task would involve asking participants to come up with possible roles that a Canadian prime minister can fulfill in a day, whereas an example of a convergent thinking task would be to ask the name of the 15<sup>th</sup> Canadian prime minister. There are many acceptable responses to the divergent thinking question, but only one correct response to the convergent thinking question. Divergent thinking tasks offer a greater opportunity for spontaneous processing and for creativity whereas convergent thinking tasks offer a greater opportunity for deliberate processing. Therefore divergent thinking tasks have also been called tasks of *creative ideation* (Fink & Benedek, 2013).

Those that score highly on tests of divergent thinking have been labeled as having a creative cognitive style (Guilford, 1950; see also Eysenck, 1993). Although divergent thinking tests show a high degree of convergent validity (Barron, 1968) and correlate to other measures of creativity (Barron & Harrington, 1981), their content validity has been challenged (Brown, 1989; Cattell, 1971; Wallach, 1971). As such, Hochevar and Bachelor (1989) recommended using divergent thinking tests to measure subcomponents of creativity, and not to measure creativity as a unified construct. Therefore divergent

thinking tests may be best used to determine divergent thinking ability or originality (Penke, 2003).

A number of researchers have measured alpha activity in the brain during divergent and convergent thinking tasks and found increased alpha during divergent thinking (Fink et al., 2007; Jauk et al., 2012; Jausovec, 1997; Krug et al., 2003). For example, in a study involving ill-defined (i.e., divergent) versus well-defined (i.e., convergent) problem solving tasks, Jausovec (1997) observed increased alpha activity in posterior brain regions when participants solved ill-defined problems but not when they solved well-defined ones. Also, in an EEG study on divergent versus convergent thinking, Krug et al. (2003) found greater alpha power during divergent thinking tasks compared to during convergent thinking tasks. Along the same lines, Fink et al. (2007) found strong frontal alpha synchronization during creative ideation tasks. In that study a number of creative ideation tasks elicited strong frontal alpha synchronization in the upper alpha band, whereas a more intelligence-related task elicited substantially less alpha synchronization. Fink et al. (2007) interpreted their findings to show that the degree of creativity inherent in a task correlates with alpha synchronization occurring in frontal brain regions. In accord with this interpretation, Jauk et al. (2012) found that divergent thinking tasks were accompanied by frontal alpha synchronization whereas convergent thinking tasks were accompanied by frontal alpha desynchronization.

Taken together, the above findings indicate that task-related alpha activity is related to type of creative thinking (i.e., convergent or divergent thinking) with divergent thinking eliciting increased alpha-band activity (Fink & Benadek, 2013).

**Alpha activity and originality of ideas.** Researchers have rarely investigated differences in brain activity occurring during the production of more or less original ideas. Grabner, Fink, and Neubauer (2007) found that the production of more original ideas elicited a different pattern of cortical activity than did the production of less original ideas. Specifically, they found greater right-hemispheric alpha synchronization during the production of more original ideas compared to less original ideas (Grabner et al., 2007). Conversely, they found no differences in activity in the left hemisphere related to more or less original ideas.

**Alpha activity and creative aptitude.** A number of researchers have found differences in alpha activity related to individual differences in aptitude for creativity (i.e., high vs. low creativity; Fink, Grabner, et al., 2009; Fink, Graif, & Neubauer, 2009; Fink & Neubauer, 2008; Jausovec, 2000; Razumnikova, 2007). For example, Jausovec (2000) found substantially greater alpha activity across the brain in both lower and upper alpha bands during divergent thinking tasks in highly creative people compared to people who are of average creativity with creativity here measured based on scores on the Torrance Tests of Creative Thinking. Similarly, Fink and Neubauer (2008), found greater alpha activity during divergent thinking tasks in people of high creativity than in people of low creativity with creativity based on originality scores on the Alternate Uses Test, and Razumnikova (2007) found that increased upper alpha power at frontal and parietal sites was related to a person's creativity as measured by originality scores on Mednick's (1962) Remote Associates Test. Fink, Grabner, et al. (2009) found that creative idea generation was associated with strong frontal alpha activity in the upper alpha band and that in participants with greater aptitude for creativity frontal alpha

activity was stronger in the right than in the left hemisphere. Conversely, there were no hemispheric differences in alpha activity for participants with less aptitude for creativity (i.e., originality). In a separate study from the same lab, Fink, Graif, & Neubauer (2009) found higher upper alpha band activity in a group of professional dancers than in a group of novice dancers who were instructed to imagine a spontaneously composed dance. Furthermore, they found that this increased alpha activity was evident during the imagination of a spontaneously composed dance and not during the imagination of a previously learned non-spontaneously composed dance (Fink & Benedek, 2013).

**Alpha activity and interventions that enhance creativity.** In a pair of studies from the same research group, researchers (Fink, Grabner, Benedek, & Neubauer, 2006; Fink, Schwab, & Papousek, 2011) have also found that training interventions have an effect on alpha synchronization during creative ideation. For example, Fink et al. (2006) observed greater originality of ideas and stronger frontal alpha activity in a group of participants trained for two weeks on divergent thinking compared to a group that didn't receive training. Also, Fink et al. (2011) investigated alpha activity in response to very brief creativity-related interventions such as being exposed to other people's creative ideas and being presented with the sounds of other people's laughter. They found that those that received training showed increased frontal alpha activity in the right hemisphere during creative ideation tasks.

**Summary of alpha during creative cognition.** In summary, the above-mentioned studies have shown that creative ideation is accompanied by increased alpha activity, particularly over frontal cortical sites (Fink et al., 2007; Jauk et al., 2012; Jausovec, 1997; Krug et al., 2003). Also, research has shown that increased alpha activity is related to an

individual's aptitude for creativity (i.e., high vs low creativity; Fink & Neubauer, 2006; Grabner et al., 2007), and that creativity training interventions lead to increased alpha activity during subsequent divergent thinking testing (Fink et al., 2006; Fink et al., 2011).

### **Interpretations of Alpha Activity During Creative Cognition**

**Increased alpha activity as cortical idling.** Initially, increased frontal alpha activity during creative ideation was assumed to signify reduced cortical activity characterized by the transient suppression of executive functions and logical-rational thought processes (Dietrich, 2003; Fink & Neubauer, 2006). This phenomenon was theorized as *cortical idling* (Pfurtscheller, 1999; Pfurtscheller, Stancak, & Neuper, 1996). However, more recent research has shown that increased frontal alpha activity may be indicative of sensory inhibition, internal focus of attention, and top down processing (Buzsáki & Draguhn, 2004; Klimesch et al., 2007; Ward, 2003).

**Increased alpha activity as internal processing.** As mentioned above, research has shown that increased alpha band activity may be related to top-down processing, sensory inhibition, and internal processing demands (Cooper, Croft, Dominey, Burgess, & Gruzelier, 2003; Sauseng et al., 2005). Sauseng et al. (2005) reported frontal alpha activity during working memory processing. They interpreted that during tasks involving working memory, a mechanism comes into effect preventing interference from distracting new stimuli from the external environment (Sauseng et al., 2005). Along the same lines, Cooper et al. (2003) found greater alpha activity during tasks involving internally directed attention in comparison to tasks involving externally directed attention.

Frontal alpha activity during creative cognition could therefore signify a mental state characterized by high internal processing demands and internally oriented attention (Knyazev, 2007). This claim is in accord with studies showing decreased alpha activity during external processing tasks as compared to during internal processing tasks (Cooper, Burgess, Croft, & Gruzelier, 2006; Cooper et al., 2003; Ray & Cole, 1985) and with studies suggesting that increased alpha reflects the inhibition of stimulus-driven, externally directed bottom-up processing (Von Stein & Sarnthein, 2000).

More recently, researchers have begun to investigate the role of internal processing mechanisms as they relate to creative ideation (Benedek, Bergner, Könen, Fink, & Neubauer, 2011; Fink, Grabner, et al., 2009). For example, Fink, Grabner, et al. (2009) used both EEG and fMRI to investigate the role of internal processing mechanisms as they relate specifically to creative ideation. In the EEG component of the study they found frontal alpha synchronization during creative cognition tasks, and during the fMRI component they found an increased BOLD response in frontal brain regions (Fink et al., 2009a). Fink and Benedek (2013) interpreted these findings to strongly suggest “that alpha synchronization during creative ideation reflects an active cognitive process rather than cortical idling” (p. 7).

Probing more directly, Benedek et al. (2011) compared alpha activity during divergent and convergent thinking tasks while controlling for top-down and bottom-up processing. They found increased frontal alpha activity only during tasks with high internal processing demands (i.e., top-down processing) compared to tasks involving externally focused attention (i.e., bottom-up processing), however they notably found increased alpha activity during both convergent and divergent thinking tasks (Benedek et

al., 2011). Benedek et al. interpreted that increased frontal alpha activity reflects a state of high internal processing demands regardless of whether a task involves divergent or convergent thinking. These findings soundly refute the cortical idling hypothesis and raise questions regarding whether alpha synchronization is related to creativity specifically. However, I interpret these findings as revealing shortcomings in the conceptualizations of creativity used in past studies in the domain. Benedek et al.'s findings reveal a need for researchers to conduct investigations on creative cognition measuring alpha synchronization as a function of a mental state characterized by internal processing and top-down inhibition of external stimuli (i.e., studies on artistic improvisation and spontaneous composition).

**Summary of interpretations of alpha.** In summary, the collective EEG findings showing increased frontal alpha activity occurring during creative cognition are quite consistent. These findings show that increased alpha activity during creative cognition most likely signifies the occurrence of a distinct processing mode occurring during spontaneous creativity that is characterized by internally oriented attention, suspension of external bottom-up stimulation, and top-down processing.

### **Heritability of Creativity**

Behavioural genetics studies on creativity have mostly focused on tests of divergent thinking, with all such studies on creativity having been twin studies (Penke, 2003). Studies on twins using the behavioural genetic method show the degree to which traits are explained by heritability (i.e., genetics), shared environmental influences, and non-shared environmental influences, with different traits showing different percentages of each of these determinants. In the behavioural genetic method monozygotic and



dizygotic twins are compared on behavioural measures. Underlying this method is the rationale that monozygotic (i.e., identical) twins share 100% of their genome, while dizygotic (i.e., fraternal) twins share only 50% on average (Penke, 2003).

In a review of ten twin studies on divergent thinking, Nichols (1978) reported that variance in ideational fluency was explained by 22% genetic influences, 39% shared environmental influences, and 39% non-shared environmental influences. Reznikoff, Domino, Bridges, and Honeyman (1973) administered ten creative ability tests to a sample of monozygotic and dizygotic adolescent twin pairs and found that scores on five Guilford tests (including the Alternate Uses Test) were explained by 25% genetic influences, 38% shared environmental influences, and 37% non-shared environmental and error variance. In a study of monozygotic and dizygotic Russian adolescent twin pairs, Grigorenko, LaBude, and Carter (1992) found that scores on the verbal component of the Torrance Test of Creative Thinking were explained by an estimated 44% genetic influences, 42% shared environmental influences, and 14% non-shared environmental and error variance influences.

In total, the heritability of originality as measured by performance on tests of divergent thinking appears to be moderate. In his review of the literature, Penke (2003) added results from Reznikoff et al. (1973) and the Grigorenko et al. (1992) studies to those summarized by Nichols (1978) and found a total of roughly 25% genetic, 38% shared environmental, and 37% non-shared environmental and error influences determining scores on divergent thinking tests. According to these percentages, heritability for divergent thinking tests appear to be lower than for personality traits in general, and substantially lower than for cognitive abilities, whereas shared

environmental influences appear to be strong in relation to the norm for a cognitive ability (Plomin, DeFries, McClearn, & Rutter, 1997). This suggests that the divergent thinking style (i.e., originality) is a cognitive ability or personality dimension determined by an interaction between genetics and environment, with environment being a substantial influence (Penke, 2003).

Researchers have also investigated the heritability of creative achievement. In a study of monozygotic and dizygotic pairs separated at birth and reunited in adulthood, Waller, Bouchard, Lykken, Tellegen, and Blacker (1993) found that the monozygotic twins showed a heritability of .54 whereas the dizygotic twins showed a heritability of -.06. Considering these findings and the opposing evidence of low to moderate heritability of divergent thinking, Waller et al. concluded that creativity is an emergenic phenomenon.

### **Creativity as an Emergenic Phenomenon**

Emergenesis (Lykken, 1982; Lykken, McGue, Tellegen, & Bouchard, 1992) is a theory describing the heritability of complex higher-order traits as determined by an interaction of multiple, fundamental, partly heritable and partly environmentally attributable traits.

In a meta-analysis of 26 studies on the personality traits of creative people, Feist (1998) concluded that “Creative people are more autonomous, introverted, open to new experiences, norm-doubting, self-confident, self-accepting, driven, ambitious, dominant, hostile, and impulsive” (p. 299). Specifically, he found the largest relationships of creativity with openness to experiences, conscientiousness, self-acceptance, hostility, and impulsivity. Feist also reviewed longitudinal studies on the chronological order of

personality and creativity and found no evidence that creative achievement determined subsequent personality traits. In sum, longitudinal studies suggest that the personality characteristics of creative people remain stable over time (Feist, 1998; Feist & Barron, 2003) This suggests that creative personality characteristics predict creative achievement, but that creative achievement does not predict creative personality characteristics (Penke, 2003).

In a comprehensive study comparing divergent thinking and personality, McCrae (1987) used five of Guilford's divergent thinking tests, as well as Gough's (1979) Creative Personality Scale and found that Openness to Experience was the only personality measure that was significantly correlated with divergent thinking. While McCrae's (1987) findings were replicated by Rawlings, Twomey, Burns, and Morris (1998), other findings have implicated Psychoticism as a trait more related to divergent thinking and originality than Openness to Experience (Rawlings, 1985; Stayte, 1977; Wallach & Kogan, 1965).

Overall, although a number of traits have been variably identified as correlating and not correlating with creativity, studies on the personality traits of creative people suggest Openness to Experience as a trait of more original people as measured by tests of divergent thinking.

Research on the heritability of personality indicates that a number of traits underlie the creative personality style. Eysenck (1993, 1995a, 1995b) theorized that the genetic underpinnings of a disposition towards creativity are the same as those underlying Psychoticism. However, in a series of later studies Peterson, Smith, and Carson (2002) and Peterson and Carson (2000) found a substantially larger association of the cognitive

processes underlying divergent thinking with Openness to Experience and Extraversion than with Psychoticism. These results suggest that the genetic underpinnings of a disposition towards originality are the same as those underlying Openness to Experience and Extraversion. These determinants have been shown to have moderate to substantial heritabilities (Heath, Eaves, & Martin, 1989; Plomin et al., 1997), and as they have been related to creativity (Goldberg, 1994; Johnson, 1994; Ostendorf & Angleitner, 1994) it can be summarized that heritable personality traits play at least a moderate and possibly a substantial role in the phenotypic expression of creativity as a trait (Penke, 2003).

In a study taking an emergenic approach, Penke (2003) investigated differences in creativity, as measured by elaboration and originality scores on an image completion task, between monozygotic and dizygotic twins while controlling for intelligence and personality factors. He found creativity to be explained by 60% genetics and less than 40% non-shared environmental influences and error variance. He found a combination of traits including Openness to Experience, General Intelligence, Extraversion, and low Conscientiousness as synergistically combining to determine creativity. In support of this notion, Openness to Experience has been found to be related to divergent thinking as measured by ideational fluency (Hocevar, 1979a, 1979c). Also, Openness to Experience is a trait that has been further deconstructed into component characteristics including intellectual curiosity, active imagination, unconventional attitudes, and preference for novelties and independence in opinion-formation (Angleitner & Ostendorf, 2003; McCrae, 1994), all of which support and are related to divergent thinking (Penke, 2003).

Therefore it can be summarized that although evidence shows only moderate heritability of a divergent thinking (i.e., original) personality style, from an emergenic

perspective a substantial amount of creativity as a whole is determined by interactions of heritable traits, with a number of necessary but not sufficient traits comprising to deliver the phenotypic expression of the cognitive ability of creativity (Asendorpf, 1999). From this perspective, a large amount of creativity may be explained by genetics, and Creativity may be conceptualized as a personality trait, consisting of a divergent thinking aptitude that can be called Originality.

### **Gagné's Theory of Talent Development**

In his differentiated model of giftedness and talent, Gagné (2005) discerned between gifts and talents, defining gifts as natural abilities or aptitudes and talents as systematically developed skills. In this model, Gagné (2005) provided a conceptual framework to explain how aptitudes develop into systematically developed skills by proposing four categories of factors influencing such development. These include interpersonal catalysts, environmental catalysts, learning and practice, and chance. He suggested that aptitudes develop into skills through informal and formal learning and practicing, and that interpersonal catalysts, environmental catalysts, and chance act as facilitators or inhibitors of such development (Gagné, 2005).

**Gifts.** Aptitudes have been categorized in numerous ways. For example, Carroll (1993) described a three-level hierarchy of abilities, Gardner (1983) described a theory of multiple intelligences, and Sternberg (1985) described a triarchic theory of intelligences. In his differentiated model of giftedness and talent, Gagné (2005) proposed four aptitude domains including intellectual, creative, socioaffective, and sensorimotor aptitudes. Amongst creative aptitudes he included problem-solving ability, imagination, and originality. Although developed in the context of giftedness, Gagné (2005) argued

“natural abilities manifest themselves in all children to a variable degree” (p. 62). As shown in the above section on the heritability of creativity as an emergent personality dimension, there is considerable evidence supporting the claim that aptitudes (i.e., originality) are stable, and are explained by an interaction of genetics and environmental influences.

**Talents.** According to Gagné (1997), talents (i.e., systematically developed skills) emerge through the development of aptitudes into trained skills in a particular domain. Gagné (1997) pointed out that aptitudes variably develop into competencies ranging from what is minimally acceptable in a domain to what is above average compared to the norm, with the label of *talented* characterizing expertise and achievement in the top 10% of a population in a domain. Although he conceptualized talent as achievement in the top 10% on a given skill relative to the normal population, the notion of talent as developed from aptitude applies to all levels of natural ability (i.e., average, low, high; Gagné, 1997). Aptitudes manifest in different ways and with varying degree depending on the context in which they are applied. For example, a sensitive palette and a finely attuned olfactory sense may predispose an individual towards high talent as a chef. As related to the current study, an aptitude of high originality may predispose an individual towards high skill as a musical improviser.

**Learning and practice.** According to Gagné (2005) aptitudes develop into skills through learning and practice. In Gagné’s (2005) model, there are four forms of aptitude development: (a) maturation, (b) informal learning, (c) formal non-institutional learning, and (d) formal institutional learning. Maturation accounts for development determined directly by genetics. For example, genetic coding dictates the development of and

growth of human skeletal structures. Informal learning refers to semantic (i.e., facts) and procedural (i.e., skills) knowledge gained through unstructured and not consciously directed everyday activities and interactions. For example, social skills are learned by children through everyday interactions with parents, siblings, and peers in non-institutional environments during activities and interactions wherein learning is not intentionally structured or planned (Bandura, 1977; Bronfenbrenner, 1989).

The final two forms of aptitude development are formal non-institutional learning, and formal institutional learning. For both of these, the term *formal* refers to the presence of purposeful by-design manners of systematically obtaining learning outcomes. By Gagné's (2005) definition, formal non-institutional learning refers to structured and planned autodidactic (i.e., self-taught) learning, whereas formal institutional learning refers to structured and planned learning that is institutionally based (e.g., going to school, enrolling in a music conservatory, attending sports camp).

Gagné (2005) noted that each of these forms contributes to the development of aptitudes in inverse proportion to its formality, whereas the opposite is true for systematically developed skills. This means that maturation factors (i.e., genetics) play the greatest role in the development of gifts, whereas formal institutional learning plays the smallest role. Conversely, formal institutional learning has the greatest effect on the development of talents (i.e., highly specialized skills), whereas maturation has the least effect.

### **Artists' Experience of Creativity**

As outlined earlier in this dissertation, I conceptualize creativity as a distinct mental state characterized by spontaneous intuitive thoughts expressed through a medium (i.e.,

musical instrument, drawing tool) in real time. Several researchers (Berkowitz, 2007; Berliner, 1994; Nardone, 1997; Nelson & Rawlings, 2007) have asked improvising artists to describe their experiences during spontaneous composition (i.e., improvisation), and a number of common themes have emerged. Among these are the perceptions of (a) dissolution of self and of time, (b) operating from an intuitive mental state, and (c) moving between intuitive and analytic mental states (Nelson & Rawlings, 2007).

**Dissolution of self.** Creative individuals have described alternating between heightened and diminished senses of self during the creative process. In an interview with Aaron Berkowitz (2010), Malcom Bilson described witnessing his voice during improvisation as arising without the sense of a conscious self making artistic choices. *Witnessing voice* is a common description of improvisers' experience wherein they report feeling as though they are conduits for self-expression, whether it is spoken, written, or musical. Along the same lines, Nardone (1997) described improvisation as a dichotomous state wherein the artist experiences "yielding," and "being present, and not present" (pp. 127-128).

Nelson and Rawlings (2007) reported artists' descriptions of the creative process. Artists described the feeling of being a witness to a deeper intuitive artistic voice or vision. These artists also described diminished feelings of self and of personal control over the creative process. Nelson and Rawlings (2007) interpreted this perception of loss of control to be a function of the temporary suspension of analytical and critical cognitive processes. Since these processes function during everyday life, artists may associate these with their sense of self and when suspended, they experience a foreign feeling that they interpret as a loss of self. In the same study, participants described themselves as the



“receiver” of ideas: again echoing the sense of being a sort of conduit for intuition (Nelson & Rawlings, 2007).

**Intuitive mental state.** Improvisers from varied musical traditions have reported their experiences of the creative process as a yielding to the subconscious, and also as a suspension of conscious (rational) control during the creative process (Berkowitz, 2010). Nelson and Rawlings (2007) described the intuitive mental state as “unmediated expression of the artist's emotions and flow of ideas while involved in the artistic activity” (p. 231).

American pianist and composer Robert Levin recounted a sense of being a witness to the subconscious during improvisation: a sense of not being in control, but rather of giving way to the subconscious voice (Berkowitz, 2010). Levin continued to describe improvisation as being analogous to the feeling of “going down the bobsled” (Berkowitz, 2010, p. 125). This can be interpreted to mean that when improvising one is following momentum not one’s own. It feels as though one is the guider of a vehicle controlled by forces other than one’s self. Along the same lines, Nardone (1997) envisioned the improvisatory experience as a divided one, where the improviser has a sense of self split into two: creator and witness. Nardone implied an unconscious voicing self and an onlooker who watches and relaxes critical and rational mental processes. Rather than relying on analysis or criticism, the creative individual relies on intuition and on an internal sense of what feels right. Another way of framing this is that in the creative space the individual suspends rationality and analytical thinking, and enters into an intuitive mental state.

**Fluctuation between intuitive and analytic mental states.** Nelson and Rawlings (2007) reported that artists experienced an alternating or “moving” between intuitive and analytic modes of engagement when immersed in creative activity. In the intuitive mode, artists felt a sense of deep connection (or melding) with the work, whereas in the analytic mode they felt a sense of distance from it. As described above, when in the intuitive mode, artists were process oriented: deeply absorbed in the work and with an intuition-based sense of what direction or choice to make “in the moment.” In the analytic mode, they were product oriented: concerned with external factors such as audience reactions and rules of the domain/craft. Artists reported regaining self-awareness (i.e., awareness of their physical bodies and of the passing of time) when they withdrew from the intuitive mode (Nelson & Rawlings, 2007). These reports are in accord with Dietrich’s (2004a) processing modes, outlined in the sections above, with the analytic mode being analogous to deliberate processing and the intuitive mode being analogous to spontaneous processing.

Therefore, it can be summarized that the experiences of improvising artists appear to be commensurate with cognitive and neurocognitive evidence supporting the notion of a spontaneous processing mode occurring during creative cognition.

### **Studies of Artistic Creativity**

Relatively few studies have used neuroscientific measures to investigate creativity in artistic domains (e.g., music, painting, dancing). In a review of the literature, Dietrich and Kanso (2010) found seven EEG studies, all of which emanated from three research groups; five fMRI studies; and one PET study. A common characteristic across these

studies was an emphasis on the ecological validity (i.e., authenticity) of the tasks involved (Dietrich & Kanso, 2010).

**EEG studies.** In studies involving the mental imagery of artistic tasks, Bhattacharya and Petsche (2002, 2005) and Petsche et al. (1997) found frontal alpha desynchronization, whereas in a study involving the mental imagery of the spontaneous composition of a free-form dance, Fink, Graif, and Neubauer (2009) found alpha synchronization. Fink, Graif, and Neubauer's (2009) results did not fit the trend of the previous findings, however it can be argued that their task had greater ecological validity, and that tasks involving visual arts recruit frontal brain regions for different or additional processes compared to non-visual arts (Dietrich & Kanso, 2010).

In total, the EEG studies did not elicit conclusive evidence regarding hemispheric specialization during artistic creativity. However, several of the studies showed increased alpha power in the right hemisphere (Fink, Graif, & Neubauer, 2009; Martindale, Hines, Mitchell, & Covello, 1984), and increased right hemispheric synchrony in other frequency bands (Bhattacharya & Petsche, 2002, 2005; Petsche et al., 1997).

**Functional Magnetic Resonance Imaging studies.** In five studies using neuroimaging methods (i.e., fMRI) to investigate artistic creativity (Bengtsson et al., 2007; Berkowitz & Ansari, 2008; Brown, Martinez, & Parsons, 2006; Kowatari et al., 2009; Solso, 2001) researchers reported activation in various areas of the prefrontal cortex. Conversely, Limb and Braun (2008) found deactivation in areas of the prefrontal cortex. As EEG alpha-band activity has been interpreted as an inverse measure of overall cortical activity, the deactivation found by Limb and Braun is in accordance with

previous findings of increased EEG alpha-band activity during creative cognition. It can be argued that Limb and Braun's study differed from the other fMRI studies on artistic creativity in that it provided the clearest opportunity for participants to engage in spontaneous processing without extraneous (i.e., distracting) semantic memory retrieval (i.e., deliberate processing). For example, Berkowitz and Ansari (2008) required participants to learn a system wherein musical notes were represented by letters, providing an extra step of mental processing. Conversely, Limb and Braun required participants to play melodic phrases on a realistic keyboard potentially permitting less distraction and more direct engagement in the spontaneous mode. In another study finding activation during improvisation, Brown et al. (2006) required participants to complete unfinished musical phrases. This may have been a task that failed to provide enough time to switch from focusing attention externally (i.e., listening) to focusing attention internally (i.e., improvising; Dietrich & Kanso, 2010). In other words, this task may not have provided enough time to switch between deliberate and spontaneous processing modes.

The collected findings indicate that there is not one specific brain area implicated in creativity, except for the frontal brain areas that may play a special role. Also, findings indicate "the role of the prefrontal cortex in creative thinking is not of the yea-or-nay kind" (Dietrich & Kanso, 2010, p. 838). Some research has found prefrontal activation during artistic creativity whereas other research has found prefrontal deactivation. To explain these opposing findings, Dietrich and Kanso (2010) postulated that, "It may be the case that there are different types of creativity, some that depend on prefrontal engagement and some that benefit from prefrontal disengagement" (p. 838). Therefore,

when investigating the neural correlates of creativity it is important to delineate different types of artistic creativity, different types of creativity tasks, and the cognitive processes and mental states underlying these. Therefore, research is needed that defines specific subareas of creativity and focuses on investigating changes in prefrontal activity during tasks that facilitate these *subcreativities*.

### **Assessment of Creativity**

The assessment of creativity has been a variegated endeavor as researchers have attempted to measure the construct using a variety of measures. These assessments have typically aimed to measure creative processes, personality and behavioural correlates of creativity, attitudes towards creativity, characteristics of creative products, and environmental factors that foster creativity (Plucker & Makel, 2010).

**Assessments of creative processes.** Assessments of creative process have been dominated by tests of divergent thinking (Plucker & Makel, 2010). Recall that tests of divergent thinking pose questions that can be answered in multiple ways, whereas tests of convergent thinking pose questions that call for a single correct response. In assessments of divergent thinking (e.g., the Alternate Uses Test), test facilitators typically provide a verbal or figural prompt upon which test-takers generate a number of responses. These responses have traditionally been measured as a composite of (a) ideational fluency (quantity of responses), (b) originality (divergent from the norm), (c) flexibility (production of different types of ideas), and (d) elaboration (extension of ideas through details).

The Torrance Tests of Creative Thinking (TTCT; Torrance, 1974) are the most commonly used tests of creative process and of divergent thinking. These tests include

verbal (e.g., Asking, Guessing Causes, Product Improvement) and figural (e.g., Picture Construction, Picture Completion, Lines/Circles) subtests that are administered and scored in a standardized manner and include detailed norms (Plucker & Makel, 2010). Although the TTCT have been the most popular tests of divergent thinking, others have been used as well including the Alternate Uses Test (Guilford, 1967). I selected the Alternate uses Test as a measure of divergent thinking for the current study and I will describe the Alternate Uses Test in detail at the end of the subsection on the assessment of creativity when I elaborate on the two assessments of creativity that I chose.

**Assessment of creative personality and behaviours.** Assessments of creative personality have typically involved self-report or external ratings to measure the personality characteristics of people that have been labeled creative. Examples of such batteries include the Big Five NEO – Five Factor Inventory (Costa & McCrae, 1992) and specific subtests of the Sixteen Personality Factor Questionnaire (Cattell, Eber, & Tatsuoka, 1970).

Researchers have also assessed creative personality through creative individuals' self-reports of their previous accomplishments and behaviours. The assumption here is that past creativity may best predict future creativity and thus aptitude for creativity. Examples of self-report assessments include the Creative Behaviour Inventory (Hocevar, 1979b), the Alpha Biological Inventory (Taylor & Ellison, 1966), the Creativity Achievement Questionnaire (CAQ; Carson, Peterson & Higgins, 2005), and the Runco Ideational Behaviour Scale (RIBS; Runco, 2008). In such measures individuals are presented with descriptions of creative achievements or behaviours, and are prompted to rate the degree to which these describe their own past experiences.

**Assessments of attitudes towards creativity.** Research on attitudes towards creativity has shown these are related to creative thinking ability (Basadur & Finkbeiner, 1985). Assessments of attitudes towards creativity typically involve the rating of agreement or disagreement with statements that reflect a preference or aversion to factors associated with creativity. Although very few exist, examples of assessments of attitudes towards creativity include two scales developed by Basadur and colleagues (Basadur & Finkbeiner, 1985; Basadur & Hausdorf, 1996; Basadur, Taggar, & Pringle, 1999; Basadur, Wakabashi & Graen, 1990; Runco & Basadur, 1993) that measure contrasting attitudes towards divergent thinking; the Preference for Active Divergence Scale measures an inclination towards divergent thinking, whereas the Preference for Premature Convergence Scale measures an aversion to divergence and open-ended responding (Plucker & Makel, 2010).

Recently, creative self-efficacy has received attention as an important area of attitude towards creativity measurement (Plucker & Makel, 2010). According to Tierney and Farmer (2002), creative self-efficacy is a concept representing a person's cumulative beliefs about his or her own creative abilities. In an example of an assessment of creative self-efficacy, Beghetto (2006) created a very brief yet succinct three-item scale wherein participants reported the extent of their agreement with positive self-beliefs regarding their ideation, novelty, and imagination abilities.

**Assessment of creative products.** Assessments of creative products may be amongst the most pragmatically applicable assessments of creativity (Plucker & Makel, 2010). In commercial environments these assessments are used to measure the creativity of new innovations and help inform of whether these are expected to yield profits.

Additionally, psychologists Runco (1989a) and Baer, Kaufman, and Gentile (2004) agree that product assessments may be amongst the most appropriate assessments of creativity. Assessments of creative products typically include the rating of artifacts of the creative process by the creator or by external adjudicators. Although several assessment of creative products are available, including the Creative Product Semantic Scale (Besemer, 1998) and the Student Product Assessment Form (Reis & Renzulli, 1991), the most commonly used is Amabile's (1982) Consensual Assessment Technique (Plucker & Makel, 2010). I selected the Consensual Assessment Technique as a method of assessing creative products in the current study and I will describe this assessment in further detail at the end of the subsection on the assessment of creativity when I elaborate on the two assessments of creativity that I chose.

**Assessments of environment factors that foster creativity.** In their review of the literature on environmental influences on creativity, Hunter, Bedell, and Mumford (2007) found that creativity was associated with a number of environmental influences (e.g., organizational structure, competition). Typically, in assessments of environmental factors associated with creativity researchers question stakeholders (e.g., employers, staff, clients) to identify the aspects of the work environment that were present during previous creative projects or experiences. As a popular measure of environmental factors fostering creativity, the KEYS: Assessing the Climate for Creativity battery (Amabile, Conti, Coon, Lazenby, & Herron, 1996) measures people's perceptions of aspects of their work environments. Overall, research from the domains of business and management has shown that work environments and creativity are related (Plucker & Makel, 2010).



**Selected assessments for the current study.** In the coming sections I describe and discuss the assessments of creativity that I selected to complement the EEG data in the current study.

*The Alternate Uses Test.* Recall that psychometric assessments of divergent thinking traditionally measure creativity as a composite of (a) ideational fluency (quantity of responses), (b) originality (divergent from the norm), and (c) flexibility (production of different types of ideas). Amongst studies on the EEG correlates of creative ideation, ideational fluency and originality have often been measured using the Alternate Uses Test (Fink, Graif, & Neubauer, 2009; Fink & Neubauer, 2008; Martindale & Hines, 1975), an assessment wherein participants free-associate different uses for a small number of common household items (e.g., newspaper, brick, etc.) within a given time limit. Several cognitive theories of creativity, including primary process cognition, defocussed attention, and associative hierarchies, have laid the foundation for the use of the Alternate Uses Test for both psychometric and research purposes (Martindale, 1999).

*Primary process cognition.* Theorists of primary process cognition suggested that consciousness operates as a spectrum of primary and secondary process states (Fromm, 1978). Primary process states are free-associative and analogical while secondary process states are logical and reality-oriented (Martindale, 1999). Kris (1952) proposed that creative individuals have a greater ability to access primary process states, and a subsequent lineage of research has supported this proposition. For example, creative individuals have been shown to report more fantasy activity, to have greater ability to remember dreams, and to be more easily hypnotized than the average person (Hudson, 1975; Lynn & Rhue, 1986; Martindale & Dailey, 1996; Wild, 1965).

*Defocused attention.* Theorists of defocused attention (Dewing & Batty, 1971; Dykes & McGhie, 1976) reported that creative individuals have a greater ability to hold a number of mental elements in mind at once than the average person, and that less creative individuals tend to focus only on singular elements. The theory of defocused attention is founded on the assumption that for analogies between mental elements to be made they must be held in working memory concurrently (Mendelsohn, 1976).

*Associative hierarchies.* The theory of associative hierarchies is one that examines the quantity of associations an individual can generate when provided with a stimulus word (or concept), as well as the relative strength of the connection between each of these responses and the original stimulus. Creative individuals generate a greater amount of associative responses, and the strength of these responses are qualitatively similar to one another (Mednick, 1962). Conversely, less creative individuals generate fewer associative responses, and the strength of association of their responses diminishes with each subsequent response. The associative hierarchies of creative individuals are therefore depicted as being flat, and those of less creative individuals as being steep.

As a free-associative measure of an individual's creative ability, the Alternate Uses Test has been used as a divergent thinking measure in several studies investigating the neural correlates of creativity (Fink, Graif, & Neubauer, 2009; Martindale & Hines, 1975). For example, Martindale and Hines (1975) found increased alpha activity when participants engaged in a three-item version of the Alternate Uses Test. They recorded EEGs as participants generated potential uses for a brick, a shoe, and a newspaper. The authors found increased alpha activity and interpreted that it "supports the hypothesis of an association between creativity and low cortical activation, specifically during tasks

that call for or allow creativity” (Martindale & Hines, 1975, p. 98). As shown earlier, research showing alpha synchronization to be related to top-down processing, has brought the notion of alpha activity as reduced cortical activity under considerable scrutiny (Klimesch et al., 2007). However, the theory of associative hierarchies remains congruent with the updated interpretation of alpha synchronization as increased activity.

*The Consensual Assessment Technique.* Developed by Amabile (1982), the Consensual Assessment Technique is a loosely bound way of measuring the creativity of products based on judgments made by independent raters. In the Consensual Assessment Technique, researchers typically refrain from imposing predetermined definitions of creativity on adjudicators, however Amabile (1982) herself defined creativity as novelty and appropriateness as agreed upon by suitable adjudicators (i.e., domain experts). Amabile (1982) suggested that adjudicators rate independently of one another, and that ratings include additional criteria such as technique and aesthetic appeal. These additional criteria provide benchmarks for discriminant validity testing, and broaden the definition of creativity to include aspects of performances and products that signify their overall value. Pearson product moment correlations are used to calculate inter-rater reliability, with coefficients of 0.70 and higher deemed acceptable. Here, inter-rater reliability is akin to construct validity following Amabile’s (1982) notion that a product is deemed creative as much as it is agreed to be so by appropriate observers. The Consensual Assessment Technique has been used extensively as a measure of between-subjects differences in creativity (Baer et al., 2004; Baer & Oldham, 2006; Hennessey, 1994; Kaufman, Baer, Cole, & Sexton, 2008), showing it to be a reliable measure with a high degree of ecological validity (Hennessey, Amabile, & Mueller, 2010).

## Summary

In the following paragraphs I will summarize the most relevant points made in the sections above. I will then outline the aims of my study, my research questions, and my hypotheses.

Creativity has been conceptualized as (a) a cognitive ability, (b) embedded in created products, and (c) a value assigned by domain experts. I conceptualize creativity as a distinct mental state, characterized by spontaneous intuitive ideation occurring in real time.

Dietrich (2004a) delineated two different processing modes occurring during cognitive ideation - a deliberate mode and a spontaneous mode. Instigated by circuits in the prefrontal cortex, deliberate processing yields thoughts that are rational, structured, and conforming to social norms, whereas spontaneous processing yields an intuitive stream of unfiltered, non-conforming thoughts. In deliberate processing, the dorsolateral prefrontal cortex is recruited in an active information retrieval process (Cabeza & Nyberg, 2000; Hasegawa et al., 1999) whereas during spontaneous processing the dorsolateral prefrontal cortex is down-regulated allowing unpremeditated ideas to surface into working memory (Dietrich, 2003).

Divergent thinking tasks involve open-ended questions with many possible answers, whereas convergent thinking tasks involve questions with only a single correct response. Divergent thinking tasks offer a greater opportunity for spontaneous processing whereas convergent thinking tasks offer a greater opportunity for deliberate processing. Those that score highly on tests of divergent thinking have been labeled as having an aptitude for originality (Eysenck, 1993).

EEG findings showing increased frontal alpha activity occurring during creative cognition are quite consistent. Research has shown that divergent thinking is accompanied by increased frontal alpha activity (Fink et al., 2007; Jauk et al., 2012; Jausovec, 1997; Krug et al., 2003), that increased alpha activity is related to creative aptitude (i.e., high vs. low creativity; Fink & Neubauer, 2006; Grabner et al., 2007), and that alpha activity increases as a result of creativity training (Fink et al., 2006; Fink et al. 2011). Initially, increased alpha was interpreted as cortical idling, however recently it has been interpreted as sensory inhibition, internal focus of attention, and top-down processing. Therefore, increased alpha activity during creative cognition suggests the occurrence of a distinct processing mode occurring during creative ideation that is analogous to the mental state that Dietrich (2004a) called a spontaneous processing mode.

In his differentiated model of gifts and talents, Gagné (2005) provided a conceptual framework explaining how aptitudes transform into systematically developed skills through informal and formal learning. Evidence shows moderate heritability of a divergent thinking (i.e., originality) aptitude, however, from an emergenic perspective a substantial amount of creativity is determined by interactions of heritable traits (Asendorpf, 1999). From this perspective, a substantial percentage of creative aptitude is explained by genetics. In Gagné's (2005) model, there are four forms of aptitude development: (a) maturation, (b) informal learning, (c) informal institutional learning, and (d) formal institutional learning. By Gagné's (2005) definition, formal non-institutional learning refers to structured and planned autodidactic learning, whereas

formal institutional learning refers to structured and planned learning that is institutionally based.

Improvising artists' descriptions of their experiences during spontaneous composition (i.e., improvisation) include perceptions of (a) a dissolution of self and of time, (b) operating from an intuitive mental state, and (c) alternating between intuitive and analytic mental states. These experiences are commensurate with cognitive and neurocognitive evidence supporting the notion of a spontaneous processing mode occurring during creative cognition.

Few studies have used neuroscientific measures to investigate artistic creativity, but Dietrich and Kanso (2010) found seven EEG studies and five fMRI studies incorporating authentic artistic tasks. Several EEG studies found frontal alpha desynchronization during artistic creativity tasks, whereas others found alpha synchronization. In four fMRI studies on artistic creativity (Bengtsson et al., 2007; Berkowitz & Ansari, 2008; Brown et al., 2006; Kowatari et al., 2009; Solso, 2001) researchers reported activation in areas of the prefrontal cortex, whereas in another fMRI study Limb and Braun (2008) found deactivation in areas of the prefrontal cortex. As EEG alpha-band activity has been interpreted as an inverse measure of cortical activity, the deactivation found by Limb and Braun is in accordance with previous findings of increased EEG alpha-band activity during creative cognition. The collected EEG and fMRI findings indicate that there is not one specific brain area implicated in artistic creativity, except for the frontal brain area. Furthermore, EEG studies did not elicit conclusive evidence regarding hemispheric specialization during artistic creativity.

However, several studies showed increased alpha power in the right hemisphere (Fink, Graif, & Neubauer, 2009; Martindale et al., 1984).

A number of neuroscientific imaging methods have been used to investigate the neural correlates of spontaneous artistic composition (Bhattacharya & Petsche, 2005; Fink, Graif, & Neubauer, 2009). Specifically, EEG has been used to investigate alpha wave activity in dancers and visual artists, and fMRI has been used in studies of musical improvisation (Berkowitz & Ansari, 2008; Limb & Braun, 2008). To date, there have been no studies using EEG to investigate frontal alpha activity during musical improvisation. Because of its high temporal accuracy, EEG is a suitable method for investigating creativity as a distinct mental state; however, neuroscientific research on improvisation has been dominated by functional magnetic resonance imaging (fMRI), which is better suited to answering questions of localization. When investigating the neural correlates of creativity it is important to delineate different types of artistic creativity. Research is needed that defines specific subareas of creativity and that focuses on frontal brain activity during these subcreativities.

### **Aims, Research Questions, and Hypotheses**

For the main part of this study I aimed to investigate (a) whether creativity can be conceptualized as a distinct mental state, and (b) whether creativity is moderated by previous domain specific education. For the purpose of empirical inquiry I narrowed these aims to investigate a specific type of creativity (i.e., improvisation), a specific domain of creativity (i.e., music), a specific group of creative people (i.e., musicians), and a specific type of neural activity (i.e., upper alpha-band synchronization in frontal brain regions).

The primary aim of this study was to use EEG to investigate whether frontal brain wave changes occurring during spontaneous creativity are different than during non-spontaneous (i.e., deliberate) creativity. Framing this aim as a research question, I asked: Does frontal alpha activity correspond to musical tasks of different creativity demands? As shown above, improvising artists' descriptions of spontaneous composition are commensurate with neurocognitive evidence that supports the notion of a spontaneous processing mode occurring during creative ideation (Fink et al., 2007; Jauk et al., 2012; Jausovec, 1997; Krug et al., 2003). EEG findings have shown that divergent thinking is accompanied by increased frontal alpha activity (Fink et al., 2007; Jauk et al., 2012). Divergent thinking tasks involve open-ended questions with many possible answers offering a greater opportunity for spontaneous processing than do convergent thinking tasks. In the first part of this study I aimed to measure frontal alpha synchronization in musicians during a rote playback task, a free improvisation task, and a listening task. While the rote playback task is analogous to a convergent thinking task, the free improvisation task is analogous to a divergent thinking task. Therefore, I expected to see patterns of neural activity during playback and during improvisation similar to those found in previous studies on alpha activity during divergent thinking tasks (Fink et al., 2007; Jauk et al., 2012; Jausovec, 1997; Krug et al., 2003) and tasks of spontaneous artistic composition (Fink, Graif, & Neubauer, 2009; Martindale et al., 1984). Namely, I hypothesized that EEGs would show increased alpha synchronization in frontal brain regions during spontaneous musical composition (i.e., improvisation) compared to during deliberate (i.e. rote) musical playing, and compared to when just listening to music. This finding would support Dietrich's (2004a) delineation of spontaneous and deliberate



processing modes during creative ideation, specifically supporting the notion that when accessing an intuitive stream of ideas people that are improvising are in a spontaneous mode. Further, differences in brain activity occurring during time intervals of spontaneous creativity would support my above outlined experiential conceptualization of creativity, specifically that creativity is a distinct mental state characterized by specific cognitive processes.

I further aimed to investigate the above differences in neural activity (i.e., frontal alpha synchronization) in participants with formal institutional training in creativity and participants without formal institutional training in creativity. EEG findings have shown that alpha activity increases as a result of creativity training (Fink et al., 2006). Also, in his differentiated model of gifts and talents, Gagné (2005) proposed that aptitudes, including those for creativity, develop into skills and talents through maturation and through learning. The most structured type of learning he defined is formal institutional learning. Therefore, I hypothesized that musicians with formal institutional training in improvisation (FITI) would show increased frontal alpha activity compared to musicians without formal institutional training in improvisation (non-FITI). This finding would support Gagné's (year) theory that skills are developed through formal institutional training. It also may imply that formal institutional training is a viable method of nurturing creativity.

The second aim of this study was to use EEG and the Alternate Uses Test to investigate the relationship between frontal alpha activity during tests of varying creativity demands (i.e., improvisation, deliberate playing, and listening) and aptitudes for divergent thinking and originality. Framed as a research question, I asked: Do

aptitudes for divergent thinking and originality correlate with frontal alpha activity during improvisation, deliberate playback, and listening? I further aimed to investigate whether this relationship would differ for those with previous formal institutional training in improvisation compared to those without previous formal institutional training in improvisation.

EEG findings have shown that increased alpha activity during divergent thinking tasks is related to aptitude for creativity (Fink, Grabner, et al., 2009; Fink, Graif, & Neubauer, 2009; Fink & Neubauer, 2008; Jausovec, 2000; Razumnikova, 2007). Therefore, I hypothesized that aptitudes for divergent thinking and originality would positively correlate with frontal alpha synchronization during improvisation, and to a lesser degree or not at all with frontal alpha synchronization during deliberate playback and during listening. This may suggest that the ability to enter into a spontaneous processing mode is related to a person's aptitude for divergent thinking and originality. This finding may suggest that some people are more predisposed than others towards entering the creative mental state. I further hypothesized that this correlation would be greater amongst those with previous formal institutional training in improvisation than those without.

The third aim of this study was to use EEG and the Consensual Assessment Technique to investigate whether alpha activity during spontaneous composition, deliberate playing, or listening predicts the quality of an individual's improvised performances as rated by domain experts. Framed as a research question, I asked: Does alpha band synchronization during spontaneous composition predict improvised performance quality as rated by domain experts? I also aimed to investigate whether this

predictive relationship would differ for those with formal institutional training in improvisation compared to those without formal institutional training in improvisation.

Research has shown that increased alpha activity is related to aptitude for creativity (Fink & Neubauer, 2008; Grabner et al., 2007) and that right hemispheric alpha synchronization is greater during the generation of more compared to less original ideas (Grabner et al., 2007). Therefore, I hypothesized that frontal alpha activity during improvisation would predict the innovative and overall quality of improvised performances as rated by domain experts. Specifically, I hypothesized that those exhibiting increased alpha activity during improvisation would also have higher rated improvised performances. I also hypothesized that this predictive relationship would be greater in those with previous formal institutional training in improvisation than those without previous formal institutional training in improvisation.

The fourth aim of this study was to investigate if aptitude for creativity mediates the relationship between frontal alpha activity and improvised performance quality. Specifically, I aimed to investigate whether the relationship between frontal alpha synchronization during improvisation and expert ratings of improvised musical performances persists when controlling for aptitudes for creativity. Therefore, my fourth research question was: Does aptitude for creativity mediate the relationship between frontal alpha synchronization during improvisation and quality of improvised performances as rated by domain experts? Given that alpha activity is related to a person's aptitude for creativity (Fink & Neubauer, 2006; Grabner et al., 2007), I hypothesized that aptitude for creativity would mediate the relationship between frontal brain activity during improvisation and expert ratings of improvised performances,

however I was uncertain of the effect size of this mediating role and if this role would be statistically significant. I further hypothesized that this mediating role would be greater in those with previous formal institutional training in improvisation than those without previous formal institutional training in improvisation.

## CHAPTER 2: Method

### Recruitment

Participants were recruited from the University of Western Ontario and from surrounding regions in southwestern Ontario. Upon gaining ethics approval, I contacted the Faculties of Education and of Music at this university and received permission to recruit (see appendix A for Ethics Approval Form). I posted 8.5 x 11 inch posters at several locations around both faculties and at high traffic areas on campus (see appendix B for Poster). Through the Associate Dean of Graduate Studies in Music, I emailed a brief description of the study with an attached letter of information to undergraduate and graduate students and to professors at the Faculty of Music (see appendix C for Letter of Information). Also, members of my advisory committee and I contacted acquaintances and inquired about participation and about other musicians possibly interested in participating. I described the study and provided letters of information to any respondents, and subsequently booked testing sessions. Word of mouth also occurred, with a number of individuals contacting me after having heard about the study from participants.

### Participants

Thirty-one musicians volunteered to participate (16 females, 18 males). The mean age was 28.1 years ( $SD = 14.3$ ) with a minimum age of 18.5 years and maximum age of 72.6 years. Participants were required to be 18 years of age or older in order to minimize the effects of neurological maturation, specifically the development of the prefrontal cortex that is amongst the last brain structures to reach adult development (Chiron et al., 1992; Chugani, Phelps, & Mazziotta, 1987). Participants could be either male or female

as my hypotheses were not about sex-related differences, and were required to have at least two months of music experience, however they were not required to have any improvisation experience. All participants included in the sample were right-handed and devoid of neurological disorders; these are standard inclusion criteria for an EEG study on creative cognition (e.g., Fink, Graif, & Neubauer, 2009). Regarding noise interference, participants were excluded if their EEGs yielded less than 15 artifact free epochs (epoch interval = 256 pts, 510 ms) in the pre-stimulus EEG recordings. Artifact rejection procedures will be elaborated in a later part of this paper. Seven participants were excluded due to excessive noise artifacts (i.e., interference in the EEGs caused by blinking), one was excluded due to handedness (i.e., being ambidextrous), and one was excluded due to identification as a statistical outlier ( $>2 SD$  above the mean) as measured by frontal alpha synchronization in the right hemisphere during an improvisation task.

After the exclusion of nine participants, 22 participants remained in the sample. Nine were female, and 13 were male. The mean age was 26.2 years ( $SD = 9.5$ ) with a minimum age of 18.5 years and a maximum age of 54.7 years. The mean music experience (i.e., amount of experience playing music) was 18.5 years ( $SD = 11.7$ ) with the least experienced having four years and the most experienced having 48 years. The mean improvisation experience (i.e., amount of experience improvising musically) was 10.2 years ( $SD = 13.1$ ) with the least experienced having no experience and the most experienced having 48 years.

I used Gagné's (2005) forms of aptitude development as a basis for grouping parameters. Recall that in Gagné's (2005) differentiated model of gifts and talents there are four forms of aptitude development with the most structured two forms being formal

non-institutional learning and formal institutional learning. By Gagné's (2005) definition, formal non-institutional learning refers to structured and planned autodidactic (i.e., self-taught) learning, whereas formal institutional learning refers to structured and planned learning that is institutionally based (e.g., going to school, enrolling in a music conservatory, attending sports camp).

The sample in the current study was split into two groups based on participants' previous training in improvisation. Those with previous formal institutional training in improvisation (FITI) were included in a group that I called *FITI*, and those without previous formal institutional training in improvisation were included in a group that I called *non-FITI*. Previous formal institutional training in this study included attendance at organized programs and courses (e.g., university, college, high school, Royal Conservatory of Music, other privately organized programs and courses lasting four weeks and more), and consistent private lessons over an extended duration (four weeks and more). Previous non-formal training included being self-taught, and descriptions such as attending an occasional workshop at events, through books and articles, by hearing and watching others, and by experimenting.

There were 12 participants in the non-FITI group. Six were female, and six were male. The mean age was 24.9 years ( $SD = 8.2$ ) with a minimum age of 18.5 years and a maximum age of 46.6 years. The mean music experience was 17.3 years ( $SD = 11.4$ ) with the least experienced having four years and the most experienced having 45 years. The mean improvisation experience was eight years ( $SD = 12.4$ ) with the least experienced having no experience and the most experienced having 45 years.

There were 10 participants in the FITI group. Three participants were female, and seven were male. The mean age was 27.7 years ( $SD = 11.1$ ) with a minimum age of 19.1 years and a maximum age of 54.7 years. The mean music experience was 19.9 years ( $SD = 12.5$ ) with the least experienced having six years and the most experienced having 48 years. The mean improvisation experience was 12.8 years ( $SD = 14.1$ ) with the least experienced having two years and the most experienced having 48 years.

## Measures

**Alternate Uses Test.** The Alternate Uses Test (Guilford, 1967) assesses four dimensions of creative ability. Fluency refers to the number of uses of a common object (e.g., a brick) provided by the test-taker, originality to the uniqueness and unusualness of ideas, flexibility to the breadth of ideas, and elaboration to the amount of detail in the ideas (Guilford, 1950). Many studies employing the Alternate Uses Test to investigate the neural correlates of creativity relied solely on scores of fluency (e.g., Fink, Graif, & Neubauer, 2009; Jauk et al., 2012; Martindale & Hines, 1975; Martindale et al., 1984), while a small number use scores of originality (e.g., Fink & Neubauer, 2008; Jung et al., 2010). Scoring and rating procedures are outlined in the Results section of this dissertation.

**Musical Improvisation Performance Questionnaire (MIPQ).** I created the Musical Improvisation Performance Questionnaire to assess the quality of improvised musical performances recorded during the testing sessions. There are 10 questions in this questionnaire, nine of which are divided into three subscales called Innovation, Technique, and Musicality, plus an overall impression item. Adjudicators rate performances using rating scales (1-10) for each question, with one representing a low



score and 10 representing a high score. (See appendix D for Musical Improvisation Performance Questionnaire).

Raters of the Musical Improvisation Performance Questionnaire were experts in musical improvisation and improvised composition. The first adjudicator was the vice-president of the Canadian division of a major international record label, the second was a professor of jazz at Humber College in Toronto, Ontario, and an elite Canadian jazz pianist, and the third was a professor of music at The University of Western Ontario, and the director of the University's jazz ensemble. The adjudicators independently rated the improvised music performances recorded during the EEG testing sessions at their own home or office. I asked the experts to score the performances in terms of their universal value (as opposed to in relation to other performances in the sample) and to judge elements of innovation in terms of *goodness* combined with novelty (as opposed to only on novelty).

### **Procedure**

Testing sessions took place in an EEG laboratory on the second floor of the Natural Sciences building at the University of Western Ontario. Parts of the study (i.e., phases) involving EEG recording took place inside a small sound proofed room, and parts involving paper and pencil questionnaires took place in an adjoining room housing a desk and chair.

Participants began by filling out a questionnaire to collect demographic data as well as data regarding musical and improvisational experience (see appendix E for Participant Information Questionnaire). They then moved to a separate room for EEG preparation. The EEG preparation procedure was as follows: (a) participants were asked

to sit in a comfortable chair; (b) participants were fitted with an elastic cap with sensors to record brain responses. Sensors on this cap were oriented according to the international 10-20 system, which provided coverage across the entire scalp; (c) using a blunt-tipped syringe, electrolyte gel was inserted into holes in the cap/sensors; (d) additional sensors were also taped to the nose to act as a reference, and on the cheeks and forehead (above and below the eyes) to monitor eye movements and blinking. Prior to attaching these sensors, the skin was cleaned using a sterile alcohol wipe. Electrode impedances were kept below  $5\Omega$  (ohms), which maximized conductance from scalp to electrode and minimized the electrodes' susceptibility to exogenous electromagnetic noise from the environment. The setup procedure took approximately 30 minutes.

After setup, participants were seated in front of a computer screen and the Alternate Uses Test (AUT; Guilford, 1967) procedures were explained to them. They were told that the computer software would present pictures of four common household items, and that each item would be displayed for three minutes. They were instructed to free associate or "come up with" as many uses for the objects as possible. For each idea, they were to press a button on the desk in front of them, and then verbalize their idea into a microphone situated above the computer screen. Participants were asked to continue free-associating ideas regarding uses for the entirety of the three minutes for each item. Household items in this study were a tin can, a sock, a pen, and a brick (see appendix F for pictures of Alternate Uses Test Items). Fifteen seconds of pre-stimulus reference activity was recorded prior the Alternate Uses Test phase. During this pre-stimulus interval participants focused on a fixation cross that was presented in the centre of the computer screen in front of them.

After completing the Alternate Uses Test phase of the testing session, a small two-octave MIDI keyboard was positioned in a manner that made it easily accessible for right-hand playing, and the procedure of the music phase of the study (outlined in the section below) was explained. Before commencing this phase, participants were briefly shown music charts for the three 16-bar music progressions to be presented during the music phase, and were told the diatonic structures native to each progression (e.g., C-blues scale, G-major scale, D-modal). These charts had notation of the chord progressions, but were devoid of melodic transcriptions (See appendix G for Music Charts).

Task conditions for the music phase progressed in the following order for each of the three pieces:

1. Listen. Participants were instructed to listen to the melody without playing.
2. Learn. Participants were told to learn to play the melody on the keyboard.
3. Imagine playback. Participants were told to imagine playing the melody as “straight” as possible and as closely to what they heard during the listen condition as possible.
4. Actual playback. Participants were prompted to physically play back the melody as closely to what they heard during the listen condition as possible.
5. Imagine improvisation. Participants were prompted to imagine improvising freely over the chord changes.
6. Actual improvisation. Participants were prompted to physically improvise freely over the chord changes.

Each of these conditions was 32-bars (approx. 80s) in duration, and participants progressed through the six conditions for each piece of music before proceeding to the next piece. For all the above conditions, participants were directed to play with right hand only. After explaining this procedure to the participants I reminded them to play with as little embellishment as possible during the playback conditions, and to be as creative and free as possible during the improvisation conditions. Fifteen seconds of pre-stimulus reference activity was recorded prior to the music phase. As before the Alternate Uses Test phase, during the pre-stimulus interval participants focused on a fixation cross that was presented on the computer screen in front of them.

During the experimental tasks (Alternate Uses Test and music tasks) outlined above, participants were presented with visual and auditory stimuli using E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA), while EEG activity was recorded from the surface of their scalp. Visual stimuli were presented using a 19 inch CRT monitor, and auditory stimuli were presented using a near-field studio monitor style speaker (five inch woofer). Both spoken ideas and MIDI keyboard music performances were recorded to hard disk as digital audio files using Apple Logic Express 8 (Apple Inc., Cupertino, CA). The music component of the study took approximately 18 minutes.

Upon completion of the music phase, the EEG and facial electrodes were removed. Participants were compensated with \$20 and given a debriefing form explaining the procedure and background of the study (see appendix H for Debriefing Form).

## EEG Procedures

**EEG acquisition.** Data were amplified at a gain of 500 using a SynAmps amplifier to boost the electrical signals received at electrodes situated over the scalp, and filtered online using 60 Hz notch and .1-100 Hz bandpass filters to limit the frequency range being recorded and minimize the intrusion of exogenous electrical noise. These data were recorded with Acquire 4.2 (Neurosoft Inc., El Paso, TX), an EEG acquisition and recording software package, at a sampling rate of 500 Hz using a 32-channel cap with sintered Ag/AgCl electrodes (Quik-Caps; Neurosoft Inc., El Paso, TX) oriented according to the international 10-20 system, and referenced to the nose-tip. The international 10-20 system is widely used as the arrangement of electrodes is according to measurements related to anatomical landmarks (Sanei & Chambers, 2007). This arrangement provides standardized electrode placement across the scalp. Linked pairs of electrooculogram (EOG) electrodes recorded horizontal (electrodes on the outer canthi) and vertical (electrodes above and below the left eye) eye movements. Impedances were kept below 5k $\Omega$ . EEG data were recorded to continuous files on hard disk. These continuous EEG files were later separated by experimental condition (e.g., Pre-stimulus, Listen, Playback, Improvisation) into unique data files.

**Artifact rejection.** Artifact rejection was conducted to eliminate muscular noise caused by vertical and horizontal eye movements. According to Neurosoft Inc. (2003), artifact rejection will “automatically reject (or accept) sweeps in which the voltage in a designated channel(s) exceeds defined criteria” (p. 102). Time regions containing blinks and other artifacts were removed using a maximum voltage criterion of  $\pm 100 \mu V$  at either horizontal (HEOG) or vertical electrooculogram (VEOG) electrode channels. When voltage in either of these channels exceeded these limitations, the surrounding

interval was rejected (Pre-artifact = 50 ms, Refractory period = 250 ms, Post-artifact = 50 ms). When referring to artifact rejection intervals, the term refractory period refers to “a span of time following the artifact during which additional artifacts will not be detected” (Neurosoft Inc., 2003, p. 105), and the pre- and post-artifact time spans refer to the interval of the rejected block (e.g., 50 ms before and 50 ms after).

**Data segmentation.** Following artifact rejection, data was separated into lengths of a pre-determined duration called *epochs*. For the purposes of this study, the continuous data was transformed into blink-free epochs spanning 510 ms in duration. This transform elicited a number of useable 510 ms sweeps per EEG file. The number of sweeps varied by participant according to the amount of noise artifacts present in the EEGs. The average number of accepted epochs/sweeps per condition was 26.95 ( $SD = 3.8$ ) for Pre-stimulus, 276.41 ( $SD = 72.4$ ) for Listen, 300.64 ( $SD = 73.0$ ) for Playback, and 286.86 ( $SD = 83.1$ ) for Improvisation. As mentioned earlier in this method section, participants whose epoch files elicited less than 15 useable sweeps during pre-stimulus baseline trials were eliminated from further analysis ( $n = 8$ ).

**Epoch averaging.** Next, the epoch sweeps were averaged into a single 510ms sweep for each condition (e.g., Pre-stimulus average, Playback average, Improvisation average). In order to arrive at a value representing task-related activity, EEGs in studies such as this (e.g., Fink, Graif, & Neubauer, 2009) are typically calculated in terms of power, as opposed to in terms of amplitude. This makes it easier to calculate activity at a particular electrode site relative to a participant’s resting baseline activity, as opposed to in terms of absolute amplitude without a baseline reference. Frequency domain averaging was performed wherein amplitude was “computed as a function of frequency”

(Neuroscan Inc., 2003, p. 107) and scaled in terms of power ( $\mu V$  squared, adapted from the Cooley-Tukey method). For this study, I selected a resolution of 1.961 Hz to define bin width for frequencies, and a range of 250 Hz to define the largest frequency computed from the entire range gathered at electrode sites. Resolution of bin width refers to the intervals by which the entire recorded frequency range is segmented and averaged. For this study, selecting a bin width of approximately 2 Hz provided frequency ranges corresponding to upper and lower bands of the spectral ranges (i.e., upper and lower alpha bands ranging from 8-10 Hz and 10-12 Hz).

During this study, I chose to focus my investigation on the upper alpha band (10-12 Hz), which is sensitive to group-wise differences in alpha synchronization related to tasks of varying creativity demands (Fink, Graif, & Neubauer, 2009). Therefore, all frontal alpha synchronization data reported in this study pertain specifically to the upper alpha band.

**Off-line filtering, bad channel elimination.** After averaging the useable epochs by power, averaged sweeps were filtered by frequency bands defined as overall alpha (8-12 Hz), low alpha (8-10 Hz), and high alpha (10-12 Hz). Electrode channel signals were visually inspected, with exceedingly noisy ones eliminated from further analysis.

**Task-related power calculations, and electrode grouping.** Finally, EEG data were calculated in terms of task related power values. These values represent the difference between cortical activity measured at an electrode site during a task *activation* interval and during a resting pre-stimulus *reference* interval. To calculate task-related power at a given electrode site, power during the reference interval was subtracted from power during the activation interval. This calculation was done for each electrode, for

each task (Listen, Playback, Improvisation), for each participant. When reporting task-related power, decreases from reference are expressed as negative values and referred to as *desynchronization*, whereas increases from reference are expressed as positive values and referred to as *synchronization* (Fink, Graif, & Neubauer, 2009)

Electrodes were grouped for analysis as Front Left (FP1, F3, F7), Front Right (FP2, F4, F8), and Front All (FP1, FP2, F3, F4, FZ, F7, F8, FT7, FT8, FC3, FC4, FCZ). These abbreviations refer to the position of EEG cap electrodes. For example, F3 refers to Frontal electrode number three, and FP1 refers to Frontal Parietal electrode number one. Electrodes with odd numbers in their abbreviation are situated over the left hemisphere, and electrodes with even numbers over the right hemisphere. The numbers themselves refer to the distance of the electrode from the midline, with larger numbers representing greater distance from that line (Luck, 2005). For example, electrode F7 is further away from midline than F3. Electrodes with a Z in their abbreviation are situated over the centre. Data from the Front Left and Front Right electrode groups were used for further comparisons and analyses in this study.



### CHAPTER 3: Results

The results section is divided into the following main subsections: (a) Demographic Differences Between Groups, (b) Reliability of Measures, (c) Electroencephalogram (d) Alternate Uses Test, (e) Musical Improvisation Performance Questionnaire, and (f) Partial Correlations. In the first subsection data are presented describing between-groups differences based on a number of demographic variables, and in the next subsection, inter-rater reliability procedures and statistical analyses are presented. In the third subsection data are presented describing neural activity occurring during music tasks. Here, a two-way repeated measures ANOVA with post hoc testing is presented showing within-groups and between-groups differences in task related upper alpha synchronization during music tasks. In the fourth subsection data are presented describing between-groups differences in scores on the Alternate Uses Test, and correlations are presented describing the relationships between Alternate Uses Test fluency and originality scores, between Alternate Uses Test scores and experience, and between Alternate Uses Test scores and task-related upper alpha synchronization during music tasks. In the next subsection data are presented describing between-groups differences in Musical Improvisation Performance Questionnaire scores, and correlations are presented describing the relationship between Musical Improvisation Performance Questionnaire subscales and task-related upper alpha synchronization during music tasks, and between Musical Improvisation Performance Questionnaire subscales and Alternate Uses Test scores. In the final subsection results from a partial correlation analysis are presented describing the relationship between neural activity occurring during Improvisation and Musical Improvisation Performance Questionnaire scores, as mediated by Alternate Uses Test originality scores.

### Demographic Differences between Groups

As mentioned above, participants were categorized into non-FITI and FITI groups based on whether they had previous formal institutional training in improvisation or not. Aside from this categorization factor, separate One-way ANOVAs were run to determine differences between non-FITI and FITI groups for each of age, music experience, and improvisation experience. There were no statistically significant differences between groups in terms of age,  $F(1,20) = .466, p = .503$ ; music experience,  $F(1,20) = .253, p = .620$ ; or improvisation experience,  $F(1,20) = .721, p = .406$ . These data show that there was homogeneity between the FITI and non-FITI groups in terms of age and experience.

### Reliability of Measures

**Alternate Uses Test.** I scored the Alternate Uses Test for both fluency and originality. Fluency scores were calculated by summing the number of ideas per participant, after eliminating redundancies. Two raters (myself and a PhD student research assistant) identified redundant ideas in participants' lists independently. The raters' scores were averaged to calculate a final (mean) fluency score for each participant.

Originality scores were assessed by assigning values for each idea. These values were between one and five, with a score of five indicating high originality and a score of one indicating low originality. Raters scored participants' ideas based on the following criteria: A score of five characterized an idea as *unique*, four as *unusual*, three as *somewhat novel*, two as *somewhat expected*, and one as *expected*. These values were further characterized as follows: five is a response expected from only 0-2 % of the population, four is expected from 2.1-5 %, three is expected from 5.1-25%, two is expected from 25-50%, and one is expected from 50% or more of the population. Then,

for each participant, the numbers of unusual (4) and unique (5) responses were summed to derive the final (mean) originality score.

A Pearson product-moment correlation was run to determine inter-rater reliability for scores of fluency and originality. There was a strong statistically significant positive correlation between rater one's fluency scores and rater two's fluency scores,  $r(20) = .981, p < 0.01$ . There was also a strong statistically significant positive correlation between rater one's originality scores and rater two's originality scores,  $r(20) = .708, p < 0.01$ . These data indicate consistency of scoring across raters for both fluency and originality.

**Music Improvisation Performance Questionnaire.** Pearson product-moment correlations were run to determine inter-rater reliability for Innovation, Technique, and Musicality scores. Correlations for all subscales between adjudicators one, two, and three are presented in Table 1. The average of all inter-rater correlations between subscales was strong,  $r(20) = .823, p < 0.01$ , indicating consistency of scoring across subscales.

Pearson product-moment correlations were also run to determine inter-rater reliability for subscale totals, and measure totals. Correlations for all subscales between adjudicators one, two, and three are presented in Table 2. The average of inter-rater correlations for subscale totals and for full measure totals was strong,  $r(20) = .838, p < 0.01$ , indicating consistency of scoring for the total questionnaire across adjudicators.

Given the inter-rater consistency in scoring of subscales, subscale totals, and overall measure totals, scores for the three adjudicators were averaged to yield composite subscale, subscale total, and measure total scores.

**Table 1***Inter-rater Correlations of Mean Subscale Scores of the Music Improvisation Performance Questionnaire by Adjudicator*

	Adj 1 Inn	Adj 1 Tech	Adj 1 Mus	Adj 2 Inn	Adj 2 Tech	Adj 2 Mus	Adj 3 Inn	Adj 3 Tech	Adj 3 Mus
Adj1 Inn	1								
Adj 1 Tech	<b>.988**</b>	1							
Adj 1 Mus	<b>.982**</b>	<b>.996**</b>	1						
Adj 2 Inn	<b>.832**</b>	<b>.849**</b>	<b>.836**</b>	1					
Adj 2 Tech	<b>.764**</b>	<b>.804**</b>	<b>.781**</b>	<b>.934**</b>	1				
Adj 2 Mus	<b>.772**</b>	<b>.810**</b>	<b>.792**</b>	<b>.921**</b>	<b>.988**</b>	1			
Adj 3 Inn	<b>.904**</b>	<b>.893**</b>	<b>.897**</b>	<b>.784**</b>	<b>.700**</b>	<b>.718**</b>	1		
Adj 3 Tech	<b>.903**</b>	<b>.902**</b>	<b>.900**</b>	<b>.847**</b>	<b>.739**</b>	<b>.755**</b>	<b>.946**</b>	1	
Adj 3 Mus	<b>.899**</b>	<b>.901**</b>	<b>.903**</b>	<b>.816**</b>	<b>.735**</b>	<b>.748**</b>	<b>.900**</b>	<b>.951**</b>	1

*Note.* Correlations are provided based on ratings for the total sample ( $n=22$ ). Bold type with \*\* denotes  $p < .01$  level, 1-tailed.

**Table 2**

*Inter-rater Correlations of Mean Subscale Totals and Mean Measure Totals of the Music Improvisation Performance Questionnaire by Adjudicator*

	Adj 1 Subscales	Adj 1 Measure	Adj 2 Subscales	Adj 2 Measure	Adj 3 Subscales	Adj 3 Measure
Adj 1 Subscales	1					
Adj 1 Measure	<b>.998**</b>	1				
Adj 2 Subscales	<b>.818**</b>	<b>.817**</b>	1			
Adj 2 Measure	<b>.822**</b>	<b>.823**</b>	<b>.998**</b>	1		
Adj 3 Subscales	<b>.925**</b>	<b>.921**</b>	<b>.786**</b>	<b>.785**</b>	1	
Adj 3 Measure	<b>.914**</b>	<b>.910**</b>	<b>.775**</b>	<b>.775**</b>	<b>.998**</b>	1

*Note.* Correlations are provided based on ratings for the total sample ( $n=22$ ). Bold type with \*\* denotes  $p < .01$  level, 1-tailed.

Pearson product-moment correlations were run to determine relationships between Musical Improvisation Performance Questionnaire subscales, subscale totals, and full measure totals with one another. The mean of correlations between subscales was strong and statistically significant,  $r(20) = .983, p < .01$ . Also, the mean of correlations between subscale totals and full measure totals was strong and statistically significant,  $r(20) = .999, p < .01$ . These correlations indicate stability of scoring across subscales, showing that the Musical Improvisation Performance Questionnaire provided a reliable measure of the overall quality of participants' performances.

### **Electroencephalogram (EEG)**

**Descriptive Data.** Frontal upper alpha synchronization in the left and right hemispheres during the Listen, Playback, and Improvisation tasks, reported as task-related power (TRP) values, are presented for FITI and non-FITI groups in Table 3. Recall that to calculate task-related power at a given electrode site, power during the reference interval is subtracted from power during the activation interval. Decreases from reference are expressed as negative values and referred to as desynchronization, whereas increases from reference are expressed as positive values and referred to as synchronization (Fink, Graif, & Neubauer, 2009). In the non-FITI group, frontal upper alpha synchronization in the left hemisphere was low during Listen ( $M = .15, SD = .67, SE = .35$ ), Playback ( $M = .06, SD = 1.00, SE = .43$ ), and Improvisation ( $M = .25, SD = 1.07, SE = .48$ ), whereas frontal upper alpha synchronization in the right hemisphere was high during Listen ( $M = 1.15, SD = 2.75, SE = .82$ ), and then moderate during Playback ( $M = .85, SD = 2.46, SE = .83$ ), and during Improvisation ( $M = .82, SD = 2.06, SE = .92$ ).

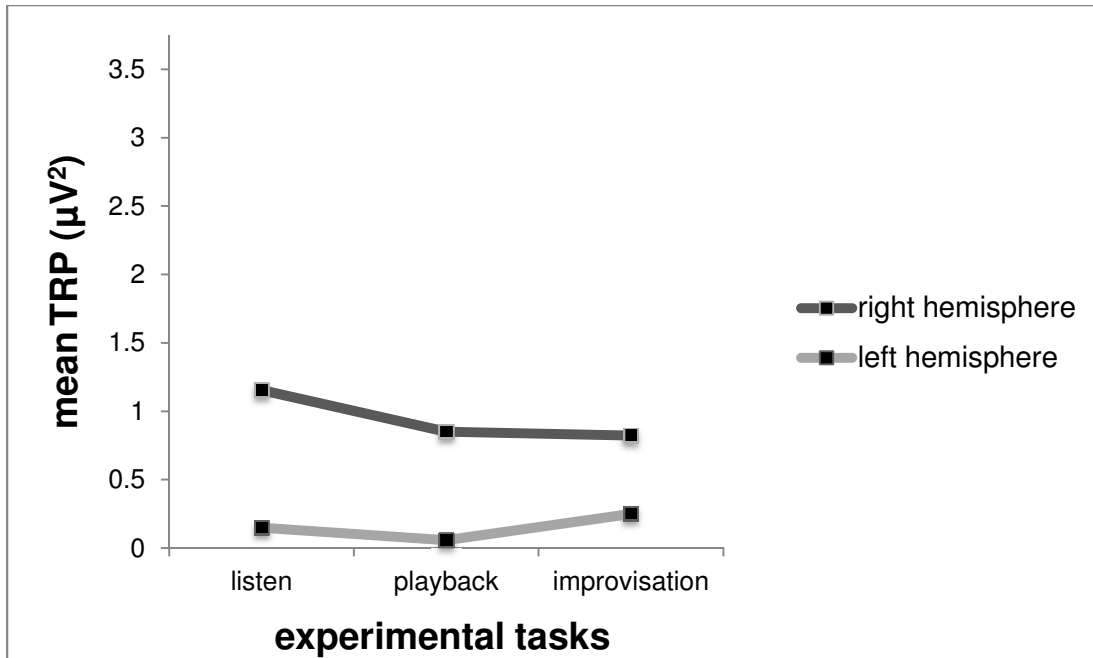
In the FITI group, frontal upper alpha synchronization in the left hemisphere was modest during Listen ( $M = .48$ ,  $SD = 1.62$ ,  $SE = .38$ ), increased during Playback ( $M = .69$ ,  $SD = 1.94$ ,  $SE = .47$ ), and increased further during Improvisation ( $M = .87$ ,  $SD = 2.19$ ,  $SE = .53$ ), while in the right hemisphere it was high during Listen ( $M = 1.19$ ,  $SD = 2.93$ ,  $SE = .90$ ) increased during Playback ( $M = 1.58$ ,  $SD = 3.28$ ,  $SE = .90$ ), and then increased to be very high during Improvisation ( $M = 2.51$ ,  $SD = 4.19$ ,  $SE = 1.00$ ).

**ANOVA.** To test within-group and between-group differences in task related upper alpha (de)synchronization during the music tasks, I employed a two-way repeated measures ANOVA.

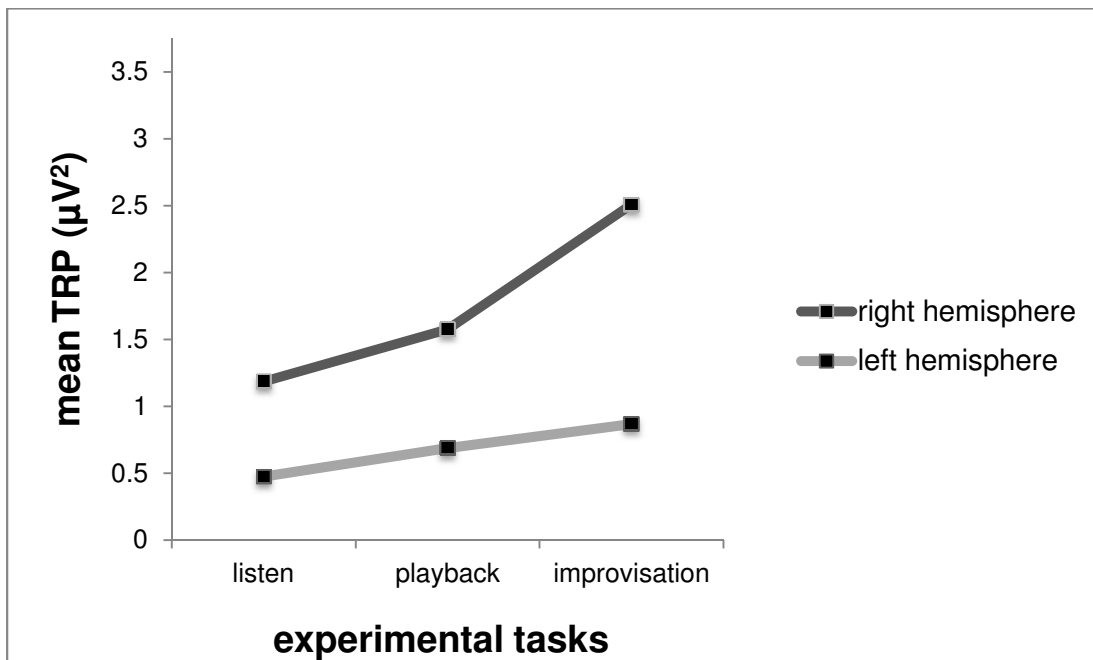
A two-way repeated measures ANOVA was calculated with training group as the between subjects factor and music task and cerebral hemisphere as within subjects factors. The task factor consisted of three levels (Listen, Playback, and Improvisation) and the hemisphere factor of two levels (left and right). The dependent variable was frontal upper alpha synchronization.

The main effects for task,  $F(2, 40) = 1.695$ ,  $p > .05$ , and hemisphere,  $F(1, 20) = 3.536$ ,  $p > .05$ , were non-significant. Also, the interactions for task by improvisation training group and hemisphere by improvisation training group were non-significant  $F(2, 40) = 2.478$ ,  $p > .05$ , and  $F(1, 20) = .084$ ,  $p > .05$ , respectively.

However, the task-by-hemisphere-by-group interaction was significant, and provided a very large effect size,  $F(2, 40) = 4.425$ ,  $p < .05$ ,  $\eta^2 = .181$ . Mauchly's test indicated that sphericity was assumed,  $X^2(2) = 3.109$ ,  $p = .211$ . Figures 1 and 2 show task related power changes in frontal upper alpha synchronization in the left and right hemispheres during the Listen, Playback, and Improvisation tasks for the non-FITI and



*Figure 1.* Frontal Upper Alpha Synchronization During Music Tasks in the Non-FIT1 Group. For the left hemisphere 95% CIs for listen, playback, and improvisation are [-.57, .87], [-.84, .96], and [-.76, 1.26] respectively and for the right hemisphere are [-.55, 2.86], [-.87, 2.57], and [-1.10, 2.75] respectively.



*Figure 2.* Frontal Upper Alpha Synchronization During Music Tasks in the FIT1 Group. For the left hemisphere 95% CIs for listen, playback, and improvisation are [-.31, 1.26], [-.30, 1.67], and [-.24, 1.97] respectively and for the right hemisphere are [-.68, 3.05], [-.31, 3.46], and [.40, 4.62] respectively.



FITI groups. Note the increase in frontal upper alpha synchronization in the right hemisphere during improvisation in Figure 2.

**Post hoc testing.** ANOVA is an omnibus test statistic that cannot reveal which specific groups within each factor significantly differ from one another. Therefore post hoc testing using Fisher's Least Significant Differences (LSD) procedure was used. Fisher's LSD was chosen to optimize the statistical power of the multiple comparisons analyses. According to Kirk (1995), Fisher's procedure is only recommended for experiments having three or less treatment levels, because when the number of treatment levels exceeds three, the test "fails to control the maximum family-wise error rate" (p. 123). Given that my study's experiment consisted of three treatment levels (Listen, Playback, and Improvisation), Fisher's LSD procedure was appropriate.

**Task-related differences.** Post hoc testing using the Fisher LSD test revealed that in the non-FITI group there was no significant difference in frontal upper alpha (de)synchronization in either hemispheres during the Improvisation task in comparison to the Playback task. Also, in the non-FITI group there was no significant difference in frontal upper alpha (de)synchronization in either hemisphere during the Improvisation task in comparison to the Listen task. Conversely, in the FITI group frontal upper alpha synchronization in the right hemisphere was different during the Improvisation task ( $M = 2.51$ ,  $SD = 4.19$ ) compared to during the Playback task ( $M = 1.58$ ,  $SD = 3.28$ ). Furthermore, in this group frontal upper alpha synchronization in the right hemisphere was different during the Improvisation task ( $M = 2.51$ ,  $SD = 4.19$ ) compared to during the Listen task ( $M = 1.19$ ,  $SD = 2.93$ ).

Taken together, these findings show differences in frontal upper alpha synchronization in the right hemisphere when musicians that have formal institutional training in improvisation improvise compared to when they engage in a rote playback task, and to when they engage in a passive listening task. Specifically, the results show that FITI musicians exhibit substantially more frontal upper alpha synchronization in the right hemisphere when engaged in the Improvisation task compared to when engaged in the rote Playback task, and even more frontal upper alpha synchronization when engaged in the Improvisation task compared to when engaged in the Listen task (see Table 3). In both comparisons, significance levels indicate a low likelihood that these findings are due to type I errors. These results show that in terms of frontal upper alpha synchronization in the right hemisphere during Improvisation the non-FITI and FITI groups are not homogeneous.

**Correlations.** Within-group correlations were run to determine the relationships between frontal upper alpha synchronization in left and right hemispheres, and between frontal upper alpha synchronization and age and experience. According to Marzban, Illian, Morison, and Mourad (2013), if data consist of groups, it is important to divide the data into components and to measure within-group correlations. Failure to acknowledge groups when they are present may result in the loss of valuable information about associations between variables. According to Muijs (2011), an effect size of approximately .30 can be considered modest, of approximately .50 can be considered moderate, and of approximately .80 can be strong. In cases when my *a priori* predictions were directional based on conceptual fit with previous research, one-tailed tests were

**Table 3***Means and Standard Deviations for Frontal High Alpha Synchronization in Left and Right Hemispheres by Training Groups*

Group	n	Left Hemisphere			Right Hemisphere		
		Listen	Playback	Improvisation	Listen	Playback	Improvisation
Non-FITI	12	.15 (.67)	.06 (1.0)	.25 (1.07)	1.15 (2.75)	.85 (2.46)	.82 (2.06)
FITI	10	.48 (1.62)	.69 (1.94)	.87 (2.19)	1.19 (2.93)	1.58 (3.28)	2.51 (4.19)

Note. In each column, mean scores are presented for each task with standard deviations in brackets. For each hemisphere, task-related changes of EEG alpha band power (TRP) in the upper alpha band (10-12 Hz) are presented from left to right in order of increasing creativity demands. Means were higher for the FITI group, wherein synchronization in the right hemisphere increased with greater task demands, peaking during improvisation.

used in order to optimize statistical power (Martella, Nelson, Morgan, & Marchand-Martella, 2013).

*Correlations of alpha synchronization in left and right hemispheres.* Pearson product-moment correlations were run to determine the relationship between frontal upper alpha synchronization in the left and right hemisphere during all tasks for non-FITI and FITI groups. In the non-FITI group there were no statistically significant correlations between frontal upper alpha synchronization in the left and right hemispheres for any tasks (see Table 4).

Conversely, in the FITI group there were strong positive correlations between frontal upper alpha synchronization in the left and right hemispheres for all tasks, with all correlations being statistically significant (see Table 5). Notably, there were correlations between frontal upper alpha synchronization in the left and right hemispheres during Listen,  $r(8) = .831, p = .001$ ; Playback  $r(8) = .847, p = .001$ ; and Improvisation  $r(8) = .747, p = .006$ . These findings show that in the FITI group, frontal upper alpha synchronization increased simultaneously across hemispheres during all tasks.

*Correlations of Task-related alpha synchronization with experience.* Pearson product-moment correlations were run to determine the relationship of frontal upper alpha synchronization in the left and right hemispheres with participant age, music experience, and improvisation experience for the non-FITI and FITI groups.

In the non-FITI group, there were no significant correlations between frontal upper alpha synchronization in the left hemisphere during Listen, Playback, and Improvisation and any of participant age, music experience, and improvisation experience. However, there were a number of moderate statistically significant negative

**Table 4**

*Non-FITI Group (n=12) Correlations between Frontal High Alpha Synchronization in Left and Right Hemispheres, by Experimental Task*

	Right Listen	Right Play	Right Improvise
Left Listen	.040	.104	-.026
Left Play	-.177	.214	.175
Left Improvise	-.413	.079	.104

Note. Correlation coefficients are provided above. For each hemisphere, tasks are presented from left to right in order of increasing creative demands. Bold type with \* would denote significance at the 0.05 level and with \*\* at the 0.01 level.

**Table 5**

*FITI Group (n=10) Correlations between Frontal High Alpha Synchronization in Left and Right Hemispheres, by Experimental Task*

	Right Listen	Right Play	Right Improvise
Left Listen	<b>.831**</b>	<b>.832**</b>	<b>.755**</b>
Left Play	<b>.825**</b>	<b>.847**</b>	<b>.739**</b>
Left Improvise	<b>.761**</b>	<b>.780**</b>	<b>.747**</b>

Note. Correlation coefficients are provided above. For each hemisphere, tasks are presented from left to right in order of increasing creative demands. Bold type with \*\* denotes significance at the 0.01 level.

correlations in the right hemisphere. These correlations were largest between Improvisation and music experience,  $r(10) = -.559, p = .029$ , and between Improvisation and improvisation experience,  $r(10) = -.579, p = .024$ . As shown in Table 6, there were also a number of moderate negative correlations between frontal upper alpha synchronization in the right hemisphere during Listen, Playback, and Improvisation, and age, music experience, and improvisation experience that were significant.

In the FITI group, there were strong statistically significant positive correlations between frontal upper alpha synchronization in the left hemisphere during all tasks, and age, music experience, and improvisation experience (see Table 7). However, in the FITI group there were no statistically significant correlations between frontal upper alpha synchronization in the right hemisphere during any tasks and age, music experience, and improvisation experience.

### **Alternate Uses Test (AUT)**

Using the t-test for independent samples, I found no significant difference in Alternate Uses Test fluency scores between the non-FITI ( $M = 39.0, SD = 14.26$ ) and FITI ( $M = 35.2, SD = 11.2$ ) groups,  $t(20) = .25, p > .05$ . Also, I found no significant difference in Alternate Uses Test originality scores between the non-FITI ( $M = 2.1, SD = 2.6$ ) and FITI ( $M = 1.4, SD = 1.5$ ) groups,  $t(20) = .75, p > .05$ . Therefore it can be summarized that the non-FITI and FITI groups did not significantly differ in terms of fluency and originality scores.

**Correlations of fluency and originality.** Pearson product-moment correlations were run to determine the relationships between fluency and with originality in the non-

**Table 6**

*Non-FITI Group (n=12) Correlations of Frontal High Alpha Synchronization During Music Tasks with Age, Music Experience, and Improvisation Experience, by Cortical Hemisphere.*

	Left Hemisphere			Right Hemisphere		
	Listen	Playback	Improvisation	Listen	Playback	Improvisation
Age	-.025	.113	.006	-.421	-.290	-.356
MUS exp	-.087	-.082	.010	-.479	<b>-.528*</b>	<b>-.559*</b>
IMPRV exp	.006	.014	.099	<b>-.514*</b>	-.471	<b>-.579*</b>

Note. Correlation coefficients are provided above. For each hemisphere, tasks are presented from left to right in order of increasing creativity demands. Bold type with \* denotes significance at the 0.05 level.

**Table 7**

*FITI Group (n=10) Correlations of Frontal High Alpha Synchronization During Music Tasks with Age, Music Experience, and Improvisation Experience, by Cortical Hemisphere.*

	Left Hemisphere			Right Hemisphere		
	Listen	Playback	Improvisation	Listen	Playback	Improvisation
Age	<b>.758**</b>	<b>.739**</b>	<b>.711*</b>	.471	.450	.390
MUS exp	<b>.745**</b>	<b>.738**</b>	<b>.752**</b>	.538	.515	.515
IMPRV exp	<b>.795**</b>	<b>.761**</b>	<b>.784**</b>	.549	.537	.542

Note. Correlation coefficients are provided above. For each hemisphere, tasks are presented from left to right in order of increasing creativity demands. Bold type with \* denotes significance at the 0.05 level and with \*\* at the 0.01 level.

FITI and FITI groups. In the non-FITI group ( $n = 12$ ), there was a moderate positive correlation between fluency and originality, which was statistically significant,  $r(11) = .685, p = .007$ . In the FITI group ( $n = 10$ ), there was a moderate positive correlation between fluency and originality, which was also statistically significant,  $r(8) = .614, p = .030$ . The similarity of these correlations across groups indicates a stable correlation of these measures with one another. I expected this, as these tests reportedly measure aspects of the same construct (Guilford, 1967).

**Correlations of fluency and originality with experience.** Pearson product-moment correlations were run to determine the relationships between fluency and originality scores and participants' age, music experience, and improvisation experience for the non-FITI and FITI groups. In both groups there were no significant correlations between fluency or originality and age and experience factors.

**Correlations of fluency and originality with task-related alpha synchronization.** Pearson product-moment correlations were run to determine the relationships between originality and fluency scores and frontal upper alpha synchronization in the right hemisphere during Listen, Playback, and Improvisation for the non-FITI group, and for the FITI group.

In both the non-FITI and FITI groups there were no significant correlations between fluency and frontal upper alpha synchronization in the right hemisphere during any of Listen, Playback, and Improvisation. Also, in the non-FITI group there were no significant correlations between originality and frontal upper alpha synchronization in any of Listen, Playback, and Improvisation (see Table 8), and in the FITI group, there were no significant correlations between originality and either Listen or Playback (see



**Table 8**

*Non-FITI Group (n = 12) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, and Frontal High Alpha Synchronization in the Right Hemisphere during Listen, Playback, and Improvisation Tasks*

	Originality	Fluency
Originality	1	
Fluency	<b>.685*</b>	1
EEG Listen	.033	.124
EEG Playback	.121	.099
EEG Improvisation	.205	.188

*Note.* Correlation coefficients are provided above. Bold type with \* denotes significance at the 0.05 level.

**Table 9**

*FITI Group (n = 10) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, and Frontal High Alpha Synchronization in the Right Hemisphere during Listen, Playback, and Improvisation Tasks*

	Originality	Fluency
Originality	1	
Fluency	<b>.614*</b>	1
EEG Listen	.359	-.058
EEG Playback	.337	-.057
EEG Improvisation	<b>.566*</b>	.176

*Note.* Correlation coefficients are provided above. Bold type with \* denotes significance at the 0.05 level.

Table 9), however there was a moderate statistically significant positive correlation between originality and frontal upper alpha synchronization in the right hemisphere during the Improvisation task,  $r(8) = .566, p = .044$ . This finding supports my hypotheses that (a) originality would be related to frontal upper alpha synchronization during Improvisation to a greater degree than during Listen and Playback, and (b) that this relationship would be greater in musicians with FITI than in musicians without.

### **Musical Improvisation Performance Questionnaire (MIPQ)**

Subscales of the Musical Improvisation Performance Questionnaire were scored on a scale of 1-10 with 10 being high. Overall, experts rated the improvised performances moderately, with the lowest score being 2.06, and the highest being 7.51. The subscale means ranged from 4.45 to 4.74 with the subscale total mean at 4.59, and the full total mean at 4.54 (see Table 10).

Using the t-test for independent samples, I found no significant differences in Musical Improvisation Performance Questionnaire Innovation, Technique, and Musicality subscale scores between the non-FITI ( $M = 4.56, 4.27, 4.36, SD = 1.3, 1.6, 1.6$ ) and FITI ( $M = 4.95, 4.68, 4.82, SD = 1.3, 1.5, 1.6$ ) groups: Innovation,  $t(20) = -.692, p = > .05$ ; Technique,  $t(20) = -.620, p > .05$ ; Musicality,  $t(20) = -.696, p > .05$ . Also, t-tests for independent samples showed no significant differences in Musical Improvisation Performance Questionnaire subscales total and overall total scores between the non-FITI ( $M = 4.40, 4.35, SD = 1.5, 1.5$ ) and FITI ( $M = 4.82, 4.77, SD = 1.5, 1.5$ ) groups: subscales total,  $t(20) = -.696, p > .05$ ; overall total,  $t(20) = -.696, p > .05$ . Therefore, it can be summarized that the non-FITI and FITI groups did not significantly differ in terms of scores on the Musical Improvisation Performance Questionnaire.

**Table 10**

*Means and Standard deviations for Subscales, Subscale Total, and Full Total of the Musical Improvisation Performance Questionnaire*

	Innovation	Technique	Musicality	Sub Total	Full Total
Non-FITI	4.6 (1.33)	4.3 (1.58)	4.4 (1.55)	4.4 (1.47)	4.3 (1.46)
FITI	4.9 (1.28)	4.7 (1.53)	4.8 (1.56)	4.8 (1.45)	4.8 (1.50)
Total	4.7 (1.29)	4.5 (1.53)	4.6 (1.54)	4.6 (1.45)	4.5 (1.46)

*Note.* The Non-FITI group ( $n=12$ ), FITI group ( $n=10$ ), and total sample ( $n=22$ ) are represented in this table. In each column, mean scores are presented for each subscale or total with standard deviations in brackets. Scores are averages from 1-10 rating scale.

I expected the Musical Improvisation Performance Questionnaire scores to be low, as adjudicators were instructed to score the performances on an absolute scale as opposed to in reference to others in the current sample, and most of the participants were not experienced jazz professionals. I also expected trained participants to score higher than non-trained participants, which was not significantly shown in these data.

#### **Correlations of MIPQ subscales with task-related alpha synchronization.**

Pearson product-moment correlations were run to determine the relationships between Musical Improvisation Performance Questionnaire subscales, subscale totals, and full measure totals and frontal upper alpha synchronization in the right hemisphere during Listen, Playback, and Improvisation for the non-FITI and FITI groups.

In the non-FITI group there were no significant correlations between any of the music rating measures and frontal upper alpha synchronization in the right hemisphere during any of Listen, Playback, or Improvisation (see Table 11). Conversely, in the FITI group there were numerous positive correlations between the Musical Improvisation Performance Questionnaire measures and frontal upper alpha synchronization in the right hemisphere during Improvisation (see Table 12). These correlations were moderate and statistically significant for the Musicality subscale,  $r(8) = .592, p = .036$ ; subscales total,  $r(8) = .560, p = .046$ ; and full measure total,  $r(8) = .561, p = .046$ . Furthermore, there were moderate correlations between frontal upper alpha synchronization in the right hemisphere during Improvisation and both the Innovation,  $r(8) = .543, p = .052$ , and Technique,  $r(8) = .539, p = .054$ , subscales, however these correlations narrowly missed statistical significance.

**Table 11**

*Non-FITI Group (n = 12) Correlations between the Musical Improvisation Performance Questionnaire Subscales, Subscale Total, and Full Total and Frontal High Alpha Synchronization in the Right Hemisphere during Music Experiment Tasks.*

	Listen	Playback	Improvise
Innovation	.147	.030	-.007
Technique	.179	.063	-.015
Musicality	.108	.016	-.074
Subscale Total	.146	.037	-.033
Full Total	.117	.018	-.053

*Note.* Bold type with \* would denote significance at the 0.05 level and with \*\* at the 0.01 level. No significant correlations at either levels or below in this table.

**Table 12**

*FITI Group (n = 10) Correlations between the Musical Improvisation Performance Questionnaire Subscales, Subscale Total, and Full Total and Frontal High Alpha Synchronization in the Right Hemisphere during Music Experiment Tasks.*

	Listen	Playback	Improvise
Innovation	.462	.423	.543
Technique	.446	.403	.539
Musicality	.488	.448	<b>.592*</b>
Subscale Total	.467	.426	<b>.560*</b>
Full Total	.461	.422	<b>.561*</b>

*Note.* Bold type with \* denotes significance at the 0.05 level and with \*\* at the 0.01 level.

**Correlations of MIPQ with AUT.** Pearson product-moment correlations were run to determine the relationships between Musical Improvisation Performance Questionnaire subscales, subscale totals, and full measure totals and Alternate Uses Test originality and fluency scores for the non-FITI and FITI groups.

In the non-FITI group, there were no significant correlations between Musical Improvisation Performance Questionnaire scores and either fluency or originality (see Table 13). In the FITI group, there were no significant correlations between Musical Improvisation Performance Questionnaire scores and fluency, however, in this group there were moderate to strong, statistically significant correlations between Musical Improvisation Performance Questionnaire subscales and originality. The Musicality subscale had the highest correlation with originality,  $r(8) = .731, p = .008$ , followed by Technique,  $r(8) = .699, p = .012$ , followed by Innovation,  $r(8) = .662, p = .018$ . Also, there were strong correlations between Musical Improvisation Performance Questionnaire subscale totals and originality,  $r(8) = .701, p = .012$ , and Musical Improvisation Performance Questionnaire full measure totals and originality,  $r(8) = .714, p = .010$ .

### **Partial Correlations**

Given the correlations found in the FITI group between frontal upper alpha synchronization and originality, frontal upper alpha synchronization and Musical Improvisation Performance Questionnaire scores, and originality and Musical Improvisation Performance Questionnaire scores, I hypothesized that originality may be a mediator between frontal upper alpha synchronization and Musical Improvisation Performance Questionnaire scores. Partial correlation is a method of determining if a

**Table 13**

*Non-FITI Group (n = 12) Correlations between Alternate Uses Test Originality, Alternate Uses Test Fluency, Musical Improvisation Performance Questionnaire Subscales, and Musical Improvisation Performance Questionnaire Totals*

	Originality	Fluency
Originality	1	
Fluency	<b>.612*</b>	1
Innovation	.121	-.167
Technique	.039	-.239
Musicality	-.013	-.282
Subscales total	.046	-.235
Full Total	.034	-.237

Note. The non-FITI group is represented in this table (n=12). Bold type with \* denotes significance at the 0.05 level and with \*\* at the 0.01 level

third variable is a mediator in a correlation between two other variables (Martella et al., 2013).

Baron and Kenny (1986) defined three criteria that need to be present in order for a variable to be considered as a mediator in a relationship between two other variables: (a) the potential mediating variable must be significantly correlated with the two other variables, (b) the two other variables must be correlated with one another, and (c) when the mediating variable is controlled for, the correlation between the two other variables must cease to be significant.

Zero order correlations in the FITI group between originality and Musical Improvisation Performance Questionnaire scores were significant and moderate to strong: Innovation,  $r(8) = .662, p = .018$ ; Technique,  $r(8) = .699, p = .012$ ; Musicality,  $r(8) = .731, p = .008$ ; Subscales Total,  $r(8) = .701, p = .012$ ; Overall Total,  $r(8) = .714, p = .010$ . Originality and frontal upper alpha synchronization in the right hemisphere during Improvisation were also significantly correlated,  $r(8) = .566, p = .044$ . Given that significant correlations were also found between frontal upper alpha synchronization in the right hemisphere during Improvisation and Musical Improvisation Performance Questionnaire scores: Musicality,  $r(8) = .592, p = .036$ ; Subscales Total,  $r(8) = .560, p = .046$ ; Overall Total,  $r(8) = .561, p = .046$ , additional analysis was conducted to determine if originality was acting as a mediating variable.

I ran a partial correlation to determine the relationship between frontal upper alpha synchronization in the right hemisphere during Improvisation and Musical Improvisation Performance Questionnaire scores, controlling for originality. In this relationship, all the earlier mentioned criteria for mediation have been met. That is (a) originality was



significantly correlated with both frontal upper alpha synchronization in the right hemisphere during Improvisation and with Musical Improvisation Performance Questionnaire scores, (b) frontal upper alpha synchronization in the right hemisphere during Improvisation was significantly correlated with Musical Improvisation Performance Questionnaire scores, and (c) the partial correlations (*1-tailed*) were non-significant when controlling for originality: Musicality,  $r(7) = .316, p = .204$ ; Subscales Total,  $r(7) = .277, p = .235$ ; Overall Total,  $r(7) = .271, p = .240$ : and were substantially reduced compared to the zero order correlation coefficients. Thus, in the FITI group the relation of frontal upper alpha synchronization in the right hemisphere during Improvisation and Musical Improvisation Performance Questionnaire scores was mediated by originality.

The above findings show that for those with previous FITI, frontal upper alpha synchronization in the right hemisphere during Improvisation predicts the quality of improvised performances. However, the above partial correlation shows that this prediction is only true for those with aptitude towards originality. This suggests that formal education in improvisation acts as a catalyst for aptitudes towards creativity.

## CHAPTER 4: Discussion

### EEG

The primary aim of this study was to investigate differences in frontal brain activity occurring between tasks with high and low creativity demands. I operationalized this aim by recording EEGs while musicians listened to, played back, and improvised jazz melodies. I hypothesized that musicians would show increased frontal upper alpha band activity during more creative tasks compared to during less creative tasks, and that this effect would be more evident in those with previous FITI than those without.

**Task-related differences in alpha synchronization.** Two-way repeated measures ANOVA showed that frontal upper alpha synchronization increased as a function of an interaction between task, hemisphere, and FITI groups. Through post hoc analysis using Fisher's LSD, I teased apart the interaction and revealed that there were significant task related differences between frontal upper alpha synchronization during Improvisation and Playback, and during Improvisation and Listen. In other words, amongst those with previous FITI, alpha synchronization was greater while musicians improvised than while they played back melodies and was even greater than while they listened to melodies.

Given Dietrich's (2004a) theory that alpha activity signifies spontaneous processing and Fink, Graif, & Neubauer's (2009) findings that showed alpha synchronization occurring during the spontaneous composition of dance pieces, I interpret the increased frontal upper alpha synchronization that occurred while musicians improvised melodies as evidence of an underlying creative mental state characterized by immersion in the spontaneous processing mode. Dietrich (2004a) conceptualized the spontaneous processing mode itself as a distinct mental state characterized by the manifestation of intuitive thoughts in working memory (Dietrich, 2004a), and I conceptualized creativity

as a distinct mental state that includes (a) engagement in an activity, (b) spontaneous processing of thoughts, and (c) the expression of these thoughts through a medium. What delineates the creative mental state from the spontaneous processing mode is that in the creative mental state the creative person is engaged in an activity and is expressing intuitive thoughts as they manifest in working memory. As such, spontaneous processing is actualized into the corporeal world; it becomes active and its bounty is externalized through expression. Accordingly, spontaneous processing is a quintessential feature of the creative mental state. In fact, it is so representative of the creative mental state that I use the terms creative mental state and spontaneous processing mode interchangeably depending on context.

Although increased frontal alpha activity during creative ideation was initially assumed to signify cortical idling (Dietrich, 2003; Pfurtscheller, 1999; Pfurtscheller et al., 1996), more recent EEG findings have consistently shown that increased alpha activity during creative cognition likely signifies internally oriented attention, suspension of external bottom-up stimulation, and top-down processing (Benedek et al., 2011; Fink & Benedek, 2013). Therefore, I interpret that top-down processing and internal focus of attention, and not cortical idling, likely characterized the creative mental state that occurred while participants in the current study improvised. In order to gain further insight into this latter interpretation further research is needed. For example, researchers could pair artists' reports (i.e., interviews) on their creative processes during improvisation with EEG recordings. In such reports, researchers could question participants on experiences that characterize top-down processing and on participants' recollections of the direction in which their attention was focused (e.g., internally,

externally) during spontaneous processing tasks compared to during deliberate processing tasks. These experiential recollections can then be compared to frontal upper alpha synchronization to see if participants with increased synchronization report experiences characteristic of top-down processing and internal focus of attention.

**Lateralization of creativity.** The ANOVA and post hoc analysis showed that amongst those with previous FITI there was significantly and substantially greater frontal upper alpha synchronization in the right hemisphere while musicians spontaneously composed melodies compared to while they played back melodies deliberately, and even greater frontal upper alpha synchronization in the right hemisphere while musicians improvised melodies compared to while they listened to melodies. It is notable that these brain-wave changes occurred in the right hemispheres of those with previous FITI.

Previous research has not conclusively established that alpha activity during creative cognition is more nascent to either the left or right hemisphere (Dietrich & Kanso, 2010). However, a pattern has emerged in the literature that may indicate a special role for the right hemisphere as related to creative ideation. Specifically, previous research has shown increased frontal alpha activity in the right hemisphere during the generation of more original ideas (Grabner et al., 2007), amongst people with high aptitudes for creativity (Fink, Grabner et al., 2009), and amongst people that have had training in creative ideation (Fink et al., 2011). Furthermore, several EEG studies on artistic creativity have shown increased alpha activity in the right hemisphere (Fink, Graif, & Neubauer, 2009; Martindale et al., 1984) and increased right hemispheric synchrony in other frequency bands (Bhattacharya & Petsche, 2002, 2005; Petsche et al., 1997). Thus, although my findings cannot conclusively support a theory of creativity as

occurring in one hemisphere or the other, the increased frontal upper alpha synchronization in the right hemisphere I found during musical improvisation indicates a special role for the frontal right brain area as implicated in the generation of original ideas (Fink & Neubauer, 2006; Grabner et al., 2007), amongst people with high aptitudes for creativity (Fink, Grabner et al., 2009), and as subject to development through training (Fink et al., 2011).

However, in the current study, amongst those with previous FITI, frontal alpha synchronization in the left hemisphere was positively correlated with frontal alpha synchronization in the right hemisphere. This correlation shows that for those with previous FITI, although task related changes in frontal alpha synchronization were significant and substantially greater in the right hemisphere, upper alpha synchronization increased in the left hemisphere as well. Thus it can be stated that although frontal upper alpha synchronization was substantially greater in the right hemisphere, it increased simultaneously across both hemispheres for all tasks. This finding is in accord with the line of research that has shown that “interhemispheric interaction and integration is vital to creativity” (Lindell, 2011, p. 493).

**Experience, alpha synchronization, and creativity.** Amongst musicians without previous FITI, frontal upper alpha synchronization in the right hemisphere was moderately negatively correlated with both musicians’ music and improvisation experience. These correlations were especially evident between frontal upper alpha synchronization occurring during improvisation and both music and improvisation experience. Conversely, amongst those with previous FITI these correlations were not evident. These findings show that amongst musicians without previous FITI, those with

more music and improvisation experience exhibit less frontal upper alpha synchronization in the right hemisphere while playing back and while improvising melodies. I interpret this as a lack of immersion in the spontaneous processing mode. This may suggest that as musicians gain experience they become set in processing musical ideas from the deliberate mode. Their lexicons of musical phrases and theoretical knowledge may increase over time, however they may approach performance from an analytical, logical, and rational processing mode. This further suggests that in general, spontaneous processing is an ability or skill developed through FITI. I call this *spontaneous processing ability*. This ability is not typically learned independently or intuitively, but rather it requires nurturing; one manner of training that the current study shows is effective in the nurturing of spontaneous processing ability is FITI. This finding is supportive of Gagné's (2005) differentiated model of gifts and talents. In this model, Gagné (2005) explained that strong aptitudes are developed into skills and talents through learning and practice. The most formalized form of such aptitude development is formal institutional learning.

### **Alternate Uses Test**

My second aim in this study was to investigate whether frontal upper alpha synchronization during music tasks of high and low creative demands is related to musicians' aptitudes for creativity. To operationalize this aim I measured musicians' aptitudes for creativity using two Alternate Uses Test scales: ideational fluency and originality. Next, I correlated the scores on these measures with frontal upper alpha synchronization in the right hemisphere occurring while musicians improvised, played back, and listened to melodies and I did this for those with FITI and those without. I

aimed to answer the question: Is spontaneous processing ability related to a person's aptitude for creativity, and is this relationship subject to a person's previous FITI? Additionally, I used these correlations as measures of construct validity for the Alternate Uses Test fluency and originality subscales. Correlations of these measures with frontal upper alpha synchronization during improvisation would suggest that fluency and originality measure similar components of creativity. Conversely, a correlation of only one of these measures with frontal upper alpha synchronization would suggest that fluency and originality measure different components of creativity or perhaps different constructs altogether. Alternatively, this finding could suggest that one of the subscales is better at measuring creative aptitude, and is preferable for use in future research on creative cognition and on spontaneous processing ability.

**Correlation of fluency and originality with alpha synchronization.** I ran correlations between Alternate Uses Test fluency and originality and frontal upper alpha synchronization in the right hemisphere of musicians while they listened to, played back, and improvised melodies. I hypothesized that both fluency and originality would positively correlate with frontal upper alpha synchronization during improvisation to a greater degree than during melody playback and during the listening condition. I interpreted that these potential correlations, between frontal upper alpha synchronization during improvisation and fluency and originality, would suggest that aptitudes for creativity predict spontaneous processing ability (i.e., creative state ability).

In the non-FITI group both fluency and originality were not related to frontal upper alpha synchronization while musicians listened to, played back, and improvised melodies. Also, for both the FITI and non-FITI groups fluency was not related to frontal

upper alpha synchronization during any of the music tasks. Likewise, in the FITI group originality was not related to frontal upper alpha synchronization occurring while musicians listened to and played back melodies. However, in the FITI group originality moderately correlated with frontal upper alpha synchronization occurring while musicians improvised melodies. In short, originality correlated with frontal upper alpha synchronization during improvisation but not during the less creative tasks, and only for those with previous FITI. Given Dietrich's (2004a) theory that frontal alpha synchronization signifies spontaneous processing, I interpret this finding to show that musicians with aptitudes for original thinking with previous FITI tended to enter into the spontaneous processing mode while improvising melodically; these musicians demonstrated increased spontaneous processing ability.

The above findings suggest that Alternate Uses Test originality is a better indicator of creative state ability and perhaps of creativity than is Alternate Uses Test fluency. This finding is important because many researchers have used fluency and not originality to measure divergent thinking (e.g., Fink, Graif, & Neubauer, 2009; Jauk et al., 2012; Martindale & Hines, 1975, Martindale et al., 1984). Thus, although it is a more time-consuming endeavor involving multiple parties rating ideas on originality, researchers should prefer originality as an indicator of divergent thinking and of creative aptitude for future research.

**FITI group differences in fluency and originality.** T-tests for independent samples showed that musicians with and without previous FITI did not significantly differ on their scores of fluency and of originality. I hypothesized that scores of fluency



and originality may be subject to previous FITI, however previous FITI alone did not have an effect on scores of these two aptitude measures.

These findings support previous research showing that aptitudes themselves are stable personality traits (Feist, 1998; Feist & Barron, 2003). If fluency and originality scores had been associated with previous FITI, this would suggest that aptitudes are related to environmental influences to a greater degree than to heritable influences. The above findings show the opposite: that education, a presumably affective environmental influence, is not related to aptitudes for creativity on its own. This finding is in accord with previous longitudinal studies suggesting that the personality traits of creative people remain stable over time (Feist, 1998; Feist & Barron, 2003).

Interestingly, t-tests for independent samples disclosed that those with previous FITI and those without previous FITI did not differ on scores of fluency and of originality. However, in the FITI group, originality correlated with frontal upper alpha synchronization during improvisation whereas in the non-FITI group it did not. This may indicate that an aptitude for originality predicts musicians' spontaneous processing ability when this aptitude has been nurtured through FITI. Furthermore, this correlation may provide confirmatory evidence that frontal upper alpha synchronization is related to creative cognition and not to another non-related phenomenon.

**Correlation of fluency and originality.** For both the FITI and non-FITI groups I ran correlations to identify the degree to which fluency and originality scores were related to one another. I predicted that the two measures would highly correlate to one another. Results from both FITI and non-FITI groups showed that fluency and originality were correlated, with a medium effect size. In other words, people who scored highly on

originality also tended to score highly on fluency. This was congruent with my hypothesis and may suggest that the two scales measure a similar aspect of creativity, however, the fact that these correlations were not stronger suggests at least some variability in their scores and that each subscale also measures something different.

**Correlation of fluency and originality with experience.** I ran correlations to investigate the relationship between aptitudes for creativity as measured by Alternate Uses Test fluency and originality and age, music experience, and improvisation experience for both FITI and non-FITI groups. I predicted that environmental factors would moderately to strongly relate with creative aptitudes although these aptitudes are partly explained by genetics (Feist, 1998). In other words, I hypothesized that as a person's experience and age increased so would that person's creative aptitude. Contrary to this hypothesis, there were no significant correlations between fluency or originality and age, music experience or improvisation experience. These findings may indirectly support previous research showing that divergent thinking and originality are aptitudes that can be conceptualized as stable personality traits less subject to environmental influences than to genetics (Feist, 1998; Feist & Barron, 2003; Penke, 2003).

### **Musical Improvisation Performance Questionnaire**

The third aim of this study was to investigate whether immersion in the creative mental state as signified by frontal upper alpha synchronization during spontaneous composition predicts the quality of spontaneously composed performances. I ran correlations between frontal upper alpha synchronization occurring while musicians improvised melodies and their scores on the Musical Improvisation Performance Questionnaire for those with and without previous FITI. I hypothesized that frontal upper

alpha synchronization occurring while musicians improvise melodies would predict the quality of their improvised performances and that this relationship would exist for those with previous FITI and not for those without. Namely, I predicted that amongst those with previous FITI, frontal upper alpha synchronization during improvisation would predict more innovative performances that would be technically better and more musical, and that experts would have a better overall impression of these performances.

**FITI group differences in Musical Improvisation Performance Questionnaire scores.** T-tests for independent samples showed that musicians with and without FITI did not significantly differ on the quality of their created products as rated by domain experts using the Musical Improvisation Performance Questionnaire. These findings suggest that previous FITI in itself is not related to the quality of musicians' improvised performances. They further suggest that the quality of musicians' improvised performances is related to factors other than FITI or to interactions of FITI with other factors. I investigated what these factors might be and will describe the results below.

**Relationship of alpha synchronization and Musical Improvisation Performance Questionnaire scores.** I ran correlations between frontal upper alpha synchronization in the right hemisphere occurring while musicians improvised melodies and Musical Improvisation Performance Questionnaire scores to determine the relationship between musicians' neural activity occurring during spontaneous composition and the quality of the products created thereupon. I hypothesized that frontal upper alpha synchronization would positively correlate with Musical Improvisation Performance Questionnaire scores. Although it is plausible that success or failure on a performance would affect frontal brain activity on subsequent performance, it

is impossible for the quality of performances to affect neural activity that occurred previously while a person was performing. Thus, such a correlation can only be one in which brain activity predicts performance quality; in other words, such a correlation suggests directionality of effect. Supportive of this line of reasoning, Feist (1998) reviewed longitudinal studies on the chronological order of personality and creativity and found no evidence that creative achievement determined subsequent personality traits. Thus, my hypothesis was that frontal upper alpha synchronization would predict Musical Improvisation Performance Questionnaire scores.

In the non-FITI group there were no significant correlations between any of the Musical Improvisation Performance Questionnaire measures and frontal upper alpha synchronization in the right hemisphere occurring while musicians listened to, played back, or improvised melodies. Conversely, in the FITI group there were several positive medium sized correlations between frontal upper alpha synchronization in the right hemisphere and Musical Improvisation Performance Questionnaire measures including correlations with Musicality, subscales total scores, and overall full measure scores. These correlations indicate that frontal upper alpha synchronization in the right hemisphere predicts the quality of improvised performances for those with previous FITI. These findings are in accord with previous research that has shown frontal alpha synchronization to be related to the originality of ideas generated during divergent thinking tasks (Fink & Neubauer, 2006; Grabner et al., 2007).

Given the findings from this and the above mentioned studies, I interpret the correlations of frontal upper alpha synchronization in the right hemisphere and Musical Improvisation Performance Questionnaire scores to show that for those with previous

FITI, immersion in the spontaneous processing mode tends to yield higher quality spontaneous compositions that are rated as being better overall by domain experts.

**Relationship of aptitudes and MIPQ scores.** I ran correlations between Alternate Uses Test fluency and originality and Musical Improvisation Performance Questionnaire scores to determine the relationship between musicians' aptitudes for creativity and the quality of their improvised performances. I predicted that aptitudes for creativity would correlate with Musical Improvisation Performance Questionnaire scores, and that this correlation would be greater for those with previous FITI than for those without. In other words, I hypothesized that FITI would catalyze the development of aptitudes for creativity into domain specific talents as evident in created products.

In the non-FITI group there were no significant correlations between either Alternate Uses Test originality or fluency and Musical Improvisation Performance Questionnaire scores. Likewise, in the FITI group there were also no significant correlations between fluency and Musical Improvisation Performance Questionnaire scores, however there were medium-sized to strong correlations between originality and all Musical Improvisation Performance Questionnaire subscales, subscale total scores, and overall measure scores. In accord with my hypotheses, these correlations indicate that aptitude for originality is related to the quality of created products for those with previous FITI and not for those without. Also, the finding that fluency does not correlate with Musical Improvisation Performance Questionnaire scores while originality does supports my suggestion that Alternate Uses Test originality is a better indicator of creative aptitude than is fluency.

These findings, in addition to the results showing that frontal upper alpha synchronization in the right hemisphere during improvisation predicts performance quality, and that frontal upper alpha synchronization in the right hemisphere during improvisation is related to aptitude for originality, suggest that aptitude may mediate the relationship of frontal upper alpha synchronization in the right hemisphere and performance quality amongst musicians with previous FITI. I explored this potential mediating relationship and describe it below.

### **Partial Correlation**

The fourth and final aim of this study was to investigate the role of aptitude for creativity as a mediator of the relationship between frontal upper alpha synchronization occurring while musicians improvise and the quality of their improvised performances. I ran a partial correlation to determine the relationship between frontal upper alpha synchronization in the right hemisphere during Improvisation and Musical Improvisation Performance Questionnaire scores while controlling for Alternate Uses Test originality. Given the literature showing that frontal alpha synchronization is related to originality of ideas (Fink & Neubauer, 2008; Grabner et al., 2007) and to aptitudes for creativity (Fink, Grabner, et al., 2009; Fink, Graif, & Neubauer, 2009; Jausovec, 2000; Razumnikova, 2007), and Gagné's (2005) explanation that aptitudes are developed into talents through formal institutional training, I predicted that for those with previous FITI, aptitude for creativity would mediate the predictive relationship between musicians' frontal upper alpha synchronization and the quality of their created products. I did not however have a clear idea of the degree to which this mediating relationship would manifest nor was I fully confident that the effect would reach statistical significance.

The partial correlation showed that for musicians with previous FITI, the correlation of frontal upper alpha synchronization in the right hemisphere occurring while musicians improvised melodies and the quality of their created products was mediated by their aptitude for originality. This finding supports Gagné (2005) who theorized that aptitudes of different kinds are developed into talents through practice and training, with the most structured form of training being formal institutional training. Specifically, my findings suggest that formal institutional training in improvisation acts as a catalyst for the development of creative gifts (e.g., aptitude for originality) into creative talents (e.g., musical improvisation ability) observable in the quality of created products (e.g., improvised performances). In short, formal institutional training makes a difference in the nurturing and development of creativity, but the aptitude to be creative is a necessary trait that must be present in the first place. When both of these factors are present, individuals tend to have high spontaneous processing ability and more readily enter into the creative mental state from which they create products that are qualitatively better as judged by field experts.

### **Implications of the Current Study**

**Teaching creativity in formal institutions.** Based on the task-related differences in upper alpha synchronization between tasks of high and low creativity demands, I conclude that creativity can be conceptualized as a distinct mental state. This finding may have implications for the way in which creativity education can be approached both in and out of formal institutions. Firstly, educators may nurture creativity by recognizing it as a distinct mental state and by using pedagogical methods that facilitate and support immersion in such a state. Broadly, this entails incorporating

process-oriented pedagogies where learners are provided with the knowledge and skills of how to enter and remain in the spontaneous processing mode. Process-oriented pedagogy is a style of teaching that focuses on facilitation of mental processes and states (Littlewood, 2009). Examples of process-oriented teaching strategies include project work, task-based instruction, descriptive assessment, and other forms of experiential learning (e.g., process writing). Advantages of process-oriented learning include transfer of skills across domains and contexts, increased student autonomy, and increased student motivation (Littlewood, 2009). Further, teachers may provide the environmental conditions that are conducive to and that support such a state. Mentor-student type educational approaches are recommended whereby teachers approach learners that are in the spontaneous processing mode and provide guidance. For example, a student of theatrical directing may be encouraged to direct a monologue scene. During this activity the teacher can observe and then join the student. The student can describe his/her process, and the teacher can share how s/he might have approached the scenario themselves. In this manner the teacher encourages the student to immerse in the spontaneous processing mode, observes, and provides guidance.

Educators may also choose to structure classes and activities to enable the spontaneous processing mode. Here, the role of the teacher shifts towards that of a facilitator of mental states. I call this a *mental state based teaching model*. In such a model the teacher organizes class time to enable different mental states including the creative state, the logical-rational state, and perhaps other states as well (e.g., meditative). In my own teaching experiences in formal institutions, I have observed a lack of awareness that these states occur. Furthermore, I estimate that the majority of current



formal institutional educational practices facilitate mostly the logical-rational mental state with the creative mental state left unattended and underdeveloped in learners.

**Lateralization of creativity.** In the current study, the creative mental state was observed in EEGs as upper alpha synchronization occurring over frontal cortical sites. Such synchronization was most evident in the right hemisphere, however as synchronization increased in the right it increased in the left as well. Recently, the notion of the right brain being the locus of creativity has been regarded as a *neuromyth* (Lindell, 2011; Lindell & Kidd, 2011), as a line of research indicates that creativity “results from the interaction and integration of information from both the left and right hemispheres” (Lindell, 2011, p. 480). However, my findings along with those from recent research on alpha activity during artistic creativity have shown that the right hemisphere may be implicated in tasks involving spontaneous processing (Dietrich & Kanso, 2010). This has implications for the understanding of creative cognition and also calls for further investigations on the distinctive role of the frontal right brain areas during different types of creativity. Also, in the current study two-way repeated measures ANOVA showed main effects for hemisphere but these effects were only significant at the 0.1 level. This miss of statistical significance may be attributable to sample size, therefore future research replicating this study with a larger sample is recommended to investigate if statistically significant hemispheric differences occur without FITI.

**Nurturing creative versus logical-rational mental states in music.** For musicians without previous FITI, age and experience negatively correlated with frontal upper alpha synchronization in the right hemisphere during musical improvisation. I interpreted this to show that for those without FITI, age and experience were related to a

decreased propensity to enter into the spontaneous processing mode. This suggests that without receiving training on how to be creative, musicians may become less creative and more logical-rational as they gain experience. Future research on this tendency is needed. For example, a potential study could investigate whether experience and education in creatively constrained musical genres (e.g., classical) leads to decreased spontaneous processing ability and less innovative products than does experience and education in creatively non-constrained genres (e.g., jazz). Further, this negative correlation of age and experience with frontal upper alpha synchronization in the right hemisphere during improvisation amongst those without previous FITI has implications for the teaching of creativity. It suggests that without training in improvisation, musicians become less creative and operate from a less creative mental state. When improvising, musicians without FITI may be more logical, perhaps calling on their semantic knowledge of music theory and of pre-rehearsed phrases that they know would work over specific chord changes. Thus, if music teachers wish to develop learners' creative aptitudes they may choose to teach spontaneous processing skills thereby facilitating the creative mental state during lessons. Conversely, for some styles of music and for some musicians it may be desirable to nurture a logical-rational mental state (i.e., deliberate processing ability) during performance. In such cases avoiding FITI may be preferable. Future EEG research is needed to see if the absence of FITI is related to the increased beta band activity that is typically associated with logical-rational thought processing. More conventionally though, musicians wishing to nurture their own creative aptitudes can be confident that FITI will yield spontaneous processing ability and better quality improvised performances.

**Nurturing aptitudes for creativity.** Fluency and originality scores were not related to previous FITI or to age or experience. This suggests that aptitudes for creativity are stable traits not associated with education for every person. However, originality was related to musicians' spontaneous processing ability during improvisation as signified by frontal upper alpha synchronization in the right hemisphere, for those with previous FITI and not for those without. This shows that although aptitudes for creativity have been found to be stable traits for most people (Feist, 1998), for those with high aptitude for originality the nurturing of these aptitudes may occur through FITI and may typically not be learned independently (e.g., without formal training).

This has implications for education in that it suggests that resources may be efficiently allocated towards identifying learners with aptitudes for creativity and providing them with FITI. This implication is especially relevant for the education of creatively gifted students. Creatively gifted students need to have their gifts nurtured if these are to manifest into talents, and FITI is an effective pathway for the development of these gifts. Policy makers interested in developing student creativity and innovation may therefore profit from investing in FITI for creatively gifted students. Future research can explore the relationships between aptitudes for creativity and both spontaneous processing ability and created product quality in samples composed solely of creatively gifted artists.

Creative aptitude may be a have or have-not trait requiring nurturing in order to manifest into talent. This could imply that in addition to there being people with high aptitudes for creativity there are also people with low or average aptitudes. For these people, training in improvisation will likely not yield statistically significant increases in

spontaneous processing ability or the novelty and innovativeness of their created products.

**Measurement of creativity.** Although Alternate Uses Test fluency and originality may measure similar aspects of the construct of creativity, results from the current study have shown that originality is a better predictor of spontaneous processing ability and created product quality. Thus, originality may be a more effective measure of aptitude for creativity than is fluency and should be the preferred Alternate Uses Test measure for future studies on creative cognition and perhaps on creativity in general. Additional research is needed to investigate the relationships of these two aptitude measures under different conceptualizations of creativity and for samples of different types of artists.

Also, the success of the Alternate Uses Test originality measure, in conjunction with the Consensual Assessment Technique, in predicting spontaneous processing ability and quality of products shows that Alternate Uses Test originality may be a valuable component of assessment batteries used to identify learners with aptitudes for creativity in educational settings. However, further research is needed on larger samples and with participants from across varied artistic and non-artistic domains in order to gain confidence in the discriminant validity of this measure for high-stakes decisions such as the placement of creatively gifted students in curriculum acceleration programs.

**Nurturing innovation.** The quality of musicians' created products was not related to previous FITI alone, however for those with previous FITI, the quality of created products correlated with their aptitudes for creativity. Furthermore, amongst musicians with FITI, immersion in the creative state yielded higher quality products as

mediated by aptitude for creativity. These findings suggest that FITI does not typically lead to significantly better products, but that for those with aptitudes for creativity FITI nurtures these aptitudes into developed talents. Further, these findings show that through FITI people with aptitudes for creativity develop spontaneous processing ability and that immersion in the spontaneous processing mode yields better products.

These findings further imply that creativity and innovation can be taught to those with aptitudes for creativity and may imply that training is in fact necessary in order to nurture in-born predispositions towards creativity. These findings also illustrate that immersion in the creative state has high cultural and economic value because it yields better products. This supports my earlier recommendation that if educators wish to increase students' innovation they should identify those with aptitudes for creativity and provide them with FITI and with opportunities to immerse in the spontaneous processing mode.

### **Limitations**

The limitations of this study are related to the method and procedure that were used, the nature of my interpretations of upper alpha synchronization, the size and nature of the sample, and the kind of the information the data analyses yielded.

The primary data collection method that I employed was EEG. Although EEG has high temporal accuracy it is limited in its spatial accuracy and in its ability to isolate specific areas over the scalp (Arden, Chavez, Grazioplene, & Jung, 2010). Also, EEG electrodes measure electrical current at the surface of the scalp after conductance through brain matter that vary in density (Arden et al., 2010). Thus, the spatial accuracy of EEG is limited. Although I have described upper alpha-band activity as occurring in frontal

brain areas and in the left and right hemispheres, such spatial claims may therefore call for caution when being interpreted.

The second measure that I employed involved a divergent thinking test called the Alternate Uses Test. Divergent thinking tests have been a cornerstone of the psychometric measurement of creativity for over half a century (Plucker & Makel, 2010). As mentioned above, Alternate Uses Test fluency is scored as the sum of ideas given in response to a prompt, with higher quantities of responses signifying greater creativity. However, the question remains as to whether sheer quantity of responses signifies creativity, a separate cognitive ability (e.g., general intelligence), or a cognitive ability that is necessary for creativity but not sufficient in itself (e.g., imagination). Conversely, there appears to be less controversy about whether Alternate Uses Test originality measures creative ability because originality measures a person's tendency towards unique and unusual ideation, the very definition of normative creativity. Therefore, when considering the usefulness of Alternate Uses Test fluency and originality for measuring creative ability, examining the psychometric characteristics and specifically the predictive validity of these measures is informative.

The reliability of divergent thinking tests, including the Alternate Uses Test is high (Runco & Albert, 1985) and the concurrent validity of divergent thinking tests are satisfactory (Plucker & Makel, 2010), however there is variation in opinions on whether divergent thinking tests predict *real-world* creative achievement (Plucker & Makel, 2010). Researchers studying the predictive validity of divergent thinking tests have typically assessed associations between divergent thinking test scores and the quantity, but not quality of creative achievements (Runco, 1986b). Consequently, Runco (1986a)

suggested the use of creative attainment indicators that measure quality and not only quantity. In the current study this criticism was addressed through the use of expert ratings of the quality of participants' improvised performances. Recall that experts rated improvised performances using the Musical Improvisation Performance Questionnaire and that findings supported the predictive validity of Alternate Uses Test originality but not fluency.

Although sometimes criticized for their predictive validity, divergent thinking tests including the Alternate Uses Test have been extensively evaluated (Plucker & Makel, 2010) and remain a popular psychometric measure of creativity (Kaufman, Plucker, & Baer, 2008). They also remain popular in neuroscientific studies of creative cognition, with researchers using the Alternate Uses Test in a number of recent studies on the EEG correlates of creative cognition (e.g., Fink, Graif, & Neubauer, 2009; Jauk et al., 2012). However, the predictive validity of divergent thinking tests remains a source of contention in the research community (Plucker & Makel, 2010). Therefore, continued research testing the predictive validity of the Alternate Uses Test, especially using ecologically valid creative attainment indicators (e.g., expert ratings of creative products), is suggested.

In addition to criticisms of their psychometric properties, divergent thinking tests have also been criticized for being influenced by coaching and intervention effects (Clapham, 1996; Hattie, 1980; Torrance, 1972a, 1988). In the current study I addressed this criticism by consistently providing only a minimal instruction of "come up with as many uses as you can" to participants during the Alternate Uses Test phase of the experimental procedure.

In this paper I interpreted increased task-related frontal upper alpha synchronization in the right hemisphere as evidence of a distinct mental state occurring during creative cognition and characterized by internal focus of attention, suppression of external stimuli, and top-down processing. My interpretations were founded on previous research (Berkowitz, 2007; Berliner, 1994; Buzsaki & Draguhn, 2004; Klimesch et al., 2007; Nardone, 1997; Nelson & Rawlings, 2007; Ward, 2003) however it is possible that the increased frontal upper alpha synchronization that I found signifies cognitive processes not related to creativity. For example, in the current study frontal alpha synchronization in the right hemisphere increased with increasing creativity demands of music tasks, however it is plausible that the increased upper alpha synchronization was related to increases in general internal focusing demands and not demands specific to creative cognition. On the other hand, it is reasonable to infer that internal focus of attention is at least a part of creative cognition. Therefore, future research that isolates the different possible processes underlying frontal upper alpha synchronization during creative and non-creative cognition during ecologically valid artistic tasks is recommended so that experts in the domain can soon agree on whether the processes underlying frontal upper alpha synchronization are creativity related or general.

The sample that I recruited for this study consisted of 22 musicians who were categorized into non-FITI and FITI groups of 12 and 10 participants. Given the size of these groups, the fact that findings were statistically significant emphasizes the importance of these findings, however, a limitation of this study's sample is that it consisted solely of musicians. Although I refer to the participants at times as artists and as people, the generalizability of these findings may be limited to populations of



musicians. Accordingly, future research is needed to conduct similar studies on samples of other types of artists (e.g., writers, visual artists, dancers) and other types of creative people (e.g., mathematicians, scientists, engineers, computer programmers).

Additionally, the sample consisted of adults between the ages of 18 and 55. This choice was made in order to minimize the effects of neurological maturation, specifically the development of the prefrontal cortex that is amongst the last brain structures to reach adult development (Chiron et al., 1992; Chugani et al., 1987). Although the educational and developmental implications of the current study are potentially impactful, they may be generalizable only to adults. In future, researchers can address this limitation by conducting similar investigations on groups at different stages of development (e.g., early childhood, late childhood, early adolescence). Although challenging, such research would shed light on the development of creativity and on limitations in spontaneous processing ability at certain ages that may exist due to the lack of prefrontal cortex development characteristic of earlier stages of maturation. If spontaneous processing ability improves with the progression of developmental stages, such research may also indirectly confirm the role of the prefrontal cortex in deliberate and spontaneous processing modes. Thus, future research replicating this study on larger and more diverse samples is recommended.

I ran a number of within-group Pearson product moment correlations in this study which yielded information about the relationship between pairs of variables within distinct groups (Marzban et al., 2013), however, the interpretations of these correlations were limited to the bounds of the groups. Thus, correlations were not compared between groups in the current study. For example, I did not state that the correlation of frontal

upper alpha synchronization in the right hemisphere occurring while musicians improvised melodies and Musical Improvisation Performance Questionnaire scores was greater amongst those with FITI than those without. I was limited to stating that the correlation was evident for those with FITI and not evident for those without.

## CHAPTER 5: Summary and Conclusions

My primary aim in this study was to investigate differences in frontal brain activity occurring between tasks with high and low creativity demands. I hypothesized that musicians would show increased frontal upper alpha band activity during tasks with high creative demands compared to those with low creative demands, and that this effect would be more evident in those with previous FITI than those without. Confirming my hypothesis, amongst those with previous FITI, upper alpha synchronization was greater while musicians improvised than while they played back and listened to melodies. I interpreted this as evidence of a creative mental state characterized by spontaneous processing, and by top-down processing and internal focus of attention. The increased frontal upper alpha synchronization that occurred in the right hemisphere during musical improvisation supports previous research implicating the frontal right brain area in creative ideation (Fink & Neubauer, 2006; Grabner et al., 2007), amongst people with high aptitudes for creativity (Fink, Grabner, et al., 2009), and as subject to development through training (Fink et al., 2011). Although the task-related differences in synchronization that I observed amongst those with previous FITI occurred in the right hemisphere, synchronization in the right correlated with synchronization in the left. Additionally, amongst musicians without previous FITI, music and improvisation experience correlated with decreased frontal upper alpha synchronization in the right hemisphere while playing back and improvising melodies. I interpreted this correlation as signifying an absence of spontaneous processing amongst those without previous FITI.

My second aim in this study was to investigate the relationship between frontal upper alpha synchronization during music tasks of high and low creativity demands and aptitudes for creativity. I hypothesized that both fluency and originality would positively

correlate with frontal upper alpha synchronization during improvisation to a greater degree than during melody playback and during the listening condition. This hypothesis was partially confirmed, as originality correlated with frontal upper alpha synchronization during improvisation but not during the tasks with lower creative demands and only for those with previous FITI, while fluency did not correlate with frontal upper alpha synchronization during any tasks for either those with or without previous FITI. I interpreted this to show that musicians with aptitudes for original thinking with previous FITI tended to spontaneously process thoughts while improvising. These findings indirectly suggest that Alternate Uses Test originality is a better indicator of creative state ability and of creativity than is fluency. Thus, future researchers should prefer originality as an indicator of divergent thinking and of aptitude for creativity.

Musicians with and without previous FITI did not significantly differ on their scores of fluency and of originality. These findings indicate that education may not be related to aptitudes for creativity on their own. Delving deeper, in the FITI group, originality correlated with frontal upper alpha synchronization during improvisation whereas in the non-FITI group it did not. This may indicate that when nurtured through FITI, aptitude for originality is associated with musicians' spontaneous processing ability. There were no significant correlations between fluency or originality and age, music experience or improvisation experience. This may indirectly support previous research framing divergent thinking and originality as stable aptitudes or personality traits (Feist, 1998).

My third aim in this study was to investigate whether frontal upper alpha synchronization occurring during improvisation predicts quality of improvised

performances. I hypothesized that frontal upper alpha synchronization occurring while musicians improvise melodies would predict the quality of their improvised performances and that this relationship would exist for those with previous FITI and not for those without. This hypothesis was confirmed. In the FITI group, frontal upper alpha synchronization in the right hemisphere correlated with Musical Improvisation Performance Questionnaire scores. I interpreted these correlations to show that for those with previous FITI, immersion in the spontaneous processing mode tends to yield higher quality improvised performances. In the FITI group, originality correlated with all Musical Improvisation Performance Questionnaire measures. These correlations indicate that for those with previous FITI aptitude for originality is associated with the quality of created products.

My fourth and final aim of this study was to investigate the role of aptitude for creativity as a mediator of the relationship between frontal alpha synchronization occurring while musicians improvise and the quality of their improvised performances. I hypothesized that for musicians with previous FITI, aptitude for creativity would mediate the relationship between frontal upper alpha synchronization during improvisation and the quality of improvised performances. Confirming this hypothesis, a partial correlation analysis showed that for those with previous FITI, the relationship of frontal upper alpha synchronization in the right hemisphere during improvisation and the quality of created products was mediated by aptitude for originality. In accord with Gagné's (2005) differentiated model of gifts and talents, this finding suggests that formal institutional training in improvisation acts as a pathway for the development of creative gifts (e.g.,

aptitude for originality) into creative talents (e.g., musical improvisation ability) observable in the quality of created products (e.g., improvised performances).

It is my hope that the findings from this study will provide neuroscientific data to inform policy, curriculum, and pedagogy geared towards nurturing creativity in learning environments. It is also my hope that the data from this study will add to a growing research base on the neural correlates of artistic creativity by employing a neuroscientific method best-suited to measuring transient brain states: EEG.

## REFERENCES

- Albert, R. S., & Runco, M. A. (1999). A history of research on creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 16-31). New York, NY: Cambridge University Press.
- Amabile, T. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology*, *43*(5), 997-1013.
- Amabile, T. (1983). *The social psychology of creativity*. New York, NY: Springer-Verlag.
- Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal*, *39*(5), 1154-1184.
- Angleitner, A., & Ostendorf, F. (2003). NEO Persönlichkeitsinventar (revidierte Form, NEO-PI-R) nach Costa und McCrae. [NEO Personality Inventory (revised version, NEO-PI-R) after Costa and McCrae.] Gottingen, Germany: Hogrefe.
- Arden, R., Chavez, R. S., Grazioplene, R., & Jung, R. E. (2010). Neuroimaging creativity: A psychometric view. *Behavioural Brain Research*, *214*(2), 143-156.
- Asendorpf, J. B. (1999). *Psychologie der Persönlichkeit* (2. Auflage). [Psychology of personality (2<sup>nd</sup> ed.).] Berlin, Germany: Springer.
- Baddeley, A. (2000). The episodic buffer: A new component of working memory. *Trends in Cognitive Sciences*, *4*, 417-423.
- Baer, J., Kaufman, J. C., & Gentile, C. A. (2004). Extension of the consensual assessment technique to nonparallel creative products. *Creativity Research Journal*, *16*(1), 113-117.

- Baer, M., & Oldham, G. R. (2006). The curvilinear relation between experienced creative time pressure and creativity: moderating effects of openness to experience and support for creativity. *Journal of Applied Psychology, 91*(4), 963.
- Bandura, A. (1977).
- Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173.
- Barron, F. (1968). *Creativity and personal freedom* (Vol. 44). New York, NY: Van Nostrand.
- Barron, F., & Harrington, D. M. (1981). Creativity, intelligence, and personality. *Annual Review of Psychology, 32*(1), 439-476.
- Basadur, M., & Finkbeiner, C. T. (1985). Measuring preference for ideation in creative problem-solving training. *The Journal of Applied Behavioral Science, 21*(1), 37-49.
- Basadur, M., & Hausdorf, P. A. (1996). Measuring divergent thinking attitudes related to creative problem solving and innovation management. *Creativity Research Journal, 9*(1), 21-32.
- Basadur, M., Taggar, S., & Pringle, P. (1999). Improving the measurement of divergent thinking attitudes in organizations. *The Journal of Creative Behavior, 33*(2), 75-111.
- Basadur, M., Wakabayashi, M., & Graen, G. B. (1990). Individual problem-solving styles and attitudes toward divergent thinking before and after training. *Creativity Research Journal, 3*(1), 22-32.



- Bazanova, O., & Aftanas, L. (2008).- The individual alpha activity indices as predictors of fluency, flexibility and originality of nonverbal creativity. *International Journal of Psychophysiology*, 69, 178.
- Beghetto, R. A. (2006). Creative self-efficacy: Correlates in middle and secondary students. *Creativity Research Journal*, 18(4), 447-457.
- Benedek, M., Bergner, S., Könen, T., Fink, A., & Neubauer, A. C. (2011). EEG alpha synchronization is related to top-down processing in convergent and divergent thinking. *Neuropsychologia*, 49(12), 3505-3511.
- Bengtsson, S., Csikszentmihalyi, M., & Ullen, F. (2007). Cortical regions involved in the generation of musical structures during improvisation in pianists. *Journal of Cognitive Neuroscience*, 19(5), 830-842.
- Berkowitz, A. (2010). *The improvising mind*. New York, NY: Oxford University Press.
- Berkowitz, A., & Ansari, D. (2008). Generation of novel motor sequences: The neural correlates of musical improvisation. *NeuroImage*, 41(2), 535-543.
- Berliner, P. F. (1994). *Thinking in jazz: The infinite art of improvisation*. Chicago, IL: University of Chicago Press.
- Besemer, S. P. (1998). Creative product analysis matrix: Testing the model structure and a comparison among products--three novel chairs. *Creativity Research Journal*, 11(4), 333-346.
- Bhattacharya, J., & Petsche, H. (2002). Shadows of artistry: Cortical synchrony during perception and imagery of visual art. *Cognitive Brain Research*, 13(2), 179-186.

- Bhattacharya, J., & Petsche, H. (2005). Drawing on mind's canvas: Differences in cortical integration patterns between artists and non-artists. *Human Brain Mapping*, 26, 1-14.
- Bronfenbrenner, U. (1989). Ecological systems theory. In R. Vasta (Ed.) *Annals of child development* (Vol. 6, pp. 187-249). Boston, MA: JAI Press, Inc.
- Brown, R. T. (1989). Creativity: What are we to measure? In J. A. Glover, R. R. Ronning, & C. R. Reynolds (Eds.), *Handbook of creativity* (pp. 3-32). New York, NY: Plenum Press.
- Brown, S., Martinez, M. J., & Parsons, L. M. (2006). Music and language side by side in the brain: A PET study of the generation of melodies and sentences. *European Journal of Neuroscience*, 23(10), 2791-2803.
- Buzsáki, G., & Draguhn, A. (2004). Neuronal oscillations in cortical networks. *Science*, 304(5679), 1926-1929.
- Cabeza, R., & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience*, 12(1), 1-47.
- Carlson, N. (2007). *Physiology of behaviour*. Amherst, MA: Pearson.
- Carroll, J.B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. New York, NY: Cambridge University Press
- Carson, S., Peterson, J. B., & Higgins, D. M. (2005). Reliability, validity, and factor structure of the Creative Achievement Questionnaire. *Creativity Research Journal*, 17(1), 37-50.
- Cattell, R. B. (1971). *Abilities: Their structure, growth, and action*. Oxford, England: Houghton Mifflin.

- Cattell, R. B., Eber, H. W., & Tatsuoka, M. M. (1970). *Handbook for the Sixteen Personality Factor Questionnaire (16 PF)*. Champaign, IL: Institute for Personality and Ability Testing.
- Chiron, C., Raynaud, C. Maziere, B., Zilbovicius, M., Laflamme, L., Masure, M. C., Dulac, O., Bourguignon, M., Syrota, A. (1992). Changes in regional cerebral blood flow during brain maturation in children and adolescents. *Journal of Nuclear Medicine: Official Publication, Society of Nuclear Medicine*, 33(5) 696-703.
- Chugani, H. T., Phelps, M. E., Mazziotta, J. C. (1987). Positron emission tomography study of human brain functional development. *Annals of Neurology* 22(4) 487-497
- Clapham, M. M. (1996). The construct validity of divergent scores in the Structure-of-Intellect Learning Abilities Test. *Educational and Psychological Measurement*, 56, 287-292
- Cooper, N. R., Burgess, A. P., Croft, R. J., & Gruzelier, J. H. (2006). Investigating evoked and induced electroencephalogram activity in task-related alpha power increases during an internally directed attention task. *Neuroreport*, 17(2), 205-208.
- Cooper, N. R., Croft, R. J., Dominey, S. J., Burgess, A. P., & Gruzelier, J. H. (2003). Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. *International Journal of Psychophysiology*, 47(1), 65-74.
- Courtney, S., Petit, L., Haxby, J., & Ungerleider, L. (1998). The role of prefrontal cortex in working memory: Examining on the contents of consciousness. *Philosophical Transactions of the Royal Society of London Series B*, 353, 1819-1828.

- Coren, S., & Schulman, M. (1971). Effects of an external stress on commonality of verbal associates. *Psychological Reports*, 28, 328-330.
- Costa, P. T., & McCrae, R. R. (1992). Normal personality assessment in clinical practice: The NEO Personality Inventory. *Psychological Assessment*, 4(1), 5-13.
- Csikszentmihalyi, M. (1988). Society, culture, person: A systems view of creativity. In R. J. Sternberg (Ed.), *The nature of creativity* (pp. 325-339). New York, NY: Cambridge University Press.
- Csikszentmihalyi, M. (1996). *Creativity*. New York, NY: Harper Collins.
- Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In R. Sternberg (Ed.), *Handbook of creativity* (pp. 313-335). New York, NY: Cambridge University Press. *Handbook of creativity*, 313-335.
- Damasio, A. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York, NY: G. P. Putnam.
- Dehaene, S., & Naccache, L. (2001). Towards a cognitive neuroscience of consciousness: Basic evidence and a workspace framework. *Cognition*, 79, 1-37.
- Dewing, K., & Battye, G. (1971). Attention deployment and non-verbal fluency. *Journal of Personality and Social Psychology*, 17, 214-218.
- Dietrich, A. (2003). Functional neuroanatomy of altered states of consciousness: The transient hypofrontality hypothesis. *Consciousness and Cognition*, 12 (2), 231-256.
- Dietrich, A. (2004a). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, 11 (6), 1011-1026.
- Dietrich, A. (2004b). Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition*, 13, 746-761.

- Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychological Bulletin*, *136*(5), 822-848.
- Dykes, M., & McGhie, A. (1976). A comparative study of attentional strategies in schizophrenics and highly creative normal subjects. *British Journal of Psychiatry*, *128*, 50-56.
- Eysenck, H. J. (1993). Creativity and personality: Suggestions for a theory. *Psychological Inquiry*, *4*(3), 147-178.
- Eysenck, H. J. (1995a). Creativity as a product of intelligence and personality. In D. H. Saklofske & M. Zeidner (Eds.), *International handbook of personality and intelligence* (pp. 231-247). US: Springer.
- Eysenck, H. J. (1995b). *Genius: The natural history of creativity* (Vol. 12). New York, NY: Cambridge University Press.
- Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review*, *2*(4), 290-309.
- Feist, G. J., & Barron, F. X. (2003). Predicting creativity from early to late adulthood: Intellect, potential, and personality. *Journal of Research in Personality*, *37*(2), 62-88.
- Fink, A., & Benedek, M. (2013). EEG alpha power and creative ideation. *Neurosci. Biobehav. Rev.* Retrieved from: <http://dx.doi.org/10.1016/j.neubiorev.2012.12.002>
- Fink, A., Benedek, M., Grabner, R., Staudt, B., & Neubauer, A. (2007). Creativity meets neuroscience: Experimental tasks for the neuroscientific study of creative thinking. *Methods*, *42*, 68-76.

- Fink, A., Grabner, R. H., Benedek, M., & Neubauer, A. C. (2006). Divergent thinking training is related to frontal electroencephalogram alpha synchronization. *European Journal of Neuroscience*, *23*(8), 2241-2246.
- Fink, A., Grabner, R. H., Benedek, M., Reishofer, G., Hauswirth, V., Fally, M., ... Neubauer, A. C. (2009). The creative brain: Investigation of brain activity during creative problem solving by means of EEG and fMRI. *Human Brain Mapping*, *30*(3), 734-748.
- Fink, A., Graif, B., & Neubauer, A. C. (2009). Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. *NeuroImage*, *46*(3), 854-862.
- Fink, A., & Neubauer, A. C. (2006). EEG alpha oscillations during the performance of verbal creativity tasks: Differential effects of sex and verbal intelligence. *International Journal of Psychophysiology*, *62*(1), 46-53.
- Fink, A., & Neubauer, A. C. (2008). Eysenck meets Martindale: The relationship between extraversion and originality from the neuroscientific perspective. *Personality and Individual Differences*, *44*(1), 299-310.
- Fink, A., Schwab, D., & Papousek, I. (2011). Sensitivity of EEG upper alpha activity to cognitive and affective creativity interventions. *International Journal of Psychophysiology*, *82*(3), 233-239.
- Friedman, R. S., & Förster, J. (2002). The influence of approach and avoidance motor actions on creative cognition. *Journal of Experimental Social Psychology*, *38*(1), 41-55.

- Fromm, E. (1978). Primary and secondary process in waking and in altered states of consciousness. *Journal of Altered States of Consciousness*, 4, 115-128.
- Fuster, J. (2000). Executive frontal functions. *Experimental Brain Research*, 133, 66-70.
- Gagné, F. (1997). Critique of Morelock's (1996) definitions of giftedness and talent. *Roeper Review*, 20(2), 76-85.
- Gagné, F. (2005). From gifts to talents. In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of giftedness* (2<sup>nd</sup> ed., pp. 98-119). New York, NY: Cambridge University Press.
- Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York, NY: Basics.
- Goldberg, L. R. (1994). Resolving a scientific embarrassment: A comment on the articles in this special issue. *European Journal of Personality*, 8(4), 351-356.
- Goldman-Rakic, P. (1992). Working memory and the mind. *Scientific American*, 261, 111-117.
- Gough, H. G. (1979). A creative personality scale for the Adjective Check List. *Journal of Personality and Social Psychology*, 37(8), 1398-1405.
- Grabner, R. H., Fink, A., & Neubauer, A. C. (2007). Brain correlates of self-rated originality of ideas: Evidence from event-related power and phase-locking changes in the EEG. *Behavioral Neuroscience*, 121(1), 224-230.
- Grigorenko, E. L., LaBude, M. C., & Carter, A. S. (1992). Similarity in general cognitive ability, creativity, and cognitive style in a sample of adolescent Russian twins. *Acta Geneticae Medicae et Gemellologicae*, 41, 65-72.

- Guilford, J. P. (1950). Creativity. *American Psychologist*, 5, 444-454.
- Guilford, J. P. (1967) *The nature of human intelligence*. New York, NY: McGraw-Hill.
- Hasegawa, I., Hayashi, T., & Miyashita, Y. (1999). Memory retrieval under the control of the prefrontal cortex. *Annals of Medicine*, 31(6), 380-387.
- Hattie, J. (1980). Should creativity tests be administered under testlike conditions? An empirical study of three alternative conditions. *Journal of Educational Psychology*, 72, 87-98.
- Heath, A. C., Eaves, L. J., & Martin, N. G. (1989). The genetic structure of personality III. Multivariate genetic item analysis of the EPQ scales. *Personality and Individual Differences*, 10(8), 877-888.
- Hennessey, B. A. (1994). The consensual assessment technique: An examination of the relationship between ratings of product and process creativity. *Creativity Research Journal*, 7(2), 193-208.
- Hennessey, B. A., Amabile, T. M., & Mueller, J. S. (2010). Chapter 46: Consensual Assessment. *Encyclopedia of Creativity*, 4th edition.
- Hocevar, D. (1979a). A comparison of statistical infrequency and subjective judgment as criteria in the measurement of originality. *Journal of Personality Assessment*, 43(3), 297-299.
- Hocevar, D. (1979b). The development of the Creative Behavior Inventory (CBI). Retrieved from: <http://eric.ed.gov/?id=ED170350>
- Hocevar, D. (1979c). Ideational fluency as a confounding factor in the measurement of originality. *Journal of Educational Psychology*, 71(2), 191-196.



- Hocevar, D., & Bachelor, P. (1989). A taxonomy and critique of measurements used in the study of creativity. In J. A. Glover, R. R. Ronning, & C. R. Reynolds (Eds.), *Handbook of creativity* (pp. 53-75). New York: Plenum.
- Hudson, L. (1975). *Human beings: The psychology of human experience*. New York, NY: Anchor.
- Hunter, S. T., Bedell, K. E., & Mumford, M. D. (2007). Climate for creativity: A quantitative review. *Creativity Research Journal*, *19*(1), 69-90.
- Jarrett, K. (1975). *The Koln concert* [Record]. Munich: ECM Records.
- Jauk, E., Benedek, M., & Neubauer, A. C. (2012). Tackling creativity at its roots: Evidence for different patterns of EEG alpha activity related to convergent and divergent modes of task processing. *International Journal of Psychophysiology*, *84*(2), 219-225.
- Jausovec, N. (1997). Differences in EEG activity during the solution of closed and open problems. *Creativity Research Journal*, *10*(4), 317-324.
- Jausovec, N. (2000). Differences in cognitive processes between gifted, intelligent, creative, and average individuals while solving complex problems: An EEG study. *Intelligence*, *28*, 213-237.
- Johnson, J. A. (1994). Clarification of factor five with the help of the AB5C model. *European Journal of Personality*, *8*(4), 311-334.
- Jung, R. E., Segall, J. M., Jeremy Bockholt, H., Flores, R. A., Smith, S. M., Chavez, R. S., & Haier, R. J. (2010). Neuroanatomy of creativity. *Human brain mapping*, *31*(3), 398-409.

- Kaufman, J. C., Baer, J., Cole, J. C., & Sexton, J. D. (2008). A comparison of expert and nonexpert raters using the consensual assessment technique. *Creativity Research Journal*, 20(2), 171-178.
- Kaufman, J. C., Plucker, J. A., & Baer, J. (2008). *Essentials of creativity assessment*. New York: Wiley.
- Kirk, R. E. (1995). *Experimental design: Procedures for the behavioral sciences* (3<sup>rd</sup> ed.). Pacific Grove, CA: Brooks/Cole.
- Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: The inhibition–timing hypothesis. *Brain Research Reviews*, 53(1), 63-88.
- Knight, R., & Grabowecky, M. (1999). Prefrontal cortex, time, and consciousness. In M. Gazzaniga, *The Cognitive Neurosciences* (2nd edition ed., pp. 1319-1337). Cambridge, MA: MIT Press.
- Knyazev, G. G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neuroscience & Biobehavioral Reviews*, 31(3), 377-395.
- Kowatari, Y., Lee, S. H., Yamamura, H., Nagamori, Y., Levy, P., Yamane, S., & Yamamoto, M. (2009). Neural networks involved in artistic creativity. *Human Brain Mapping*, 30(5), 1678-1690.
- Kris, E. (1952). *Psychoanalytic explorations in art*. New York, NY: International Universities Press.
- Krug, R., MÃ¼lle, M., Dodt, C., Fehm, H. L., & Born, J. (2003). Acute influences of estrogen and testosterone on divergent and convergent thinking in postmenopausal women. *Neuropsychopharmacology*, 28 (8), 1538-1545.

- Lhermitte, F. (1983). "Utilization behaviour" and its relation to lesions of the frontal lobes. *Brain*, *106*, 237-255.
- Lhermitte, F., Pillon, B., & Serdaru, M. (1986). Human autonomy and the frontal lobes. Part I: Imitation and utilization behavior: A neuropsychological study of 75 patients. *Annals of Neurology*, *19*, 326-334.
- Limb, C. J., & Braun, A. R. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *PLoS ONE*, *3*(2), 1-9.
- Lindell, A. K. (2011). Lateral thinkers are not so laterally minded: hemispheric asymmetry, interaction, and creativity. *Laterality: Asymmetries of Body, Brain and Cognition*, *16*(4), 479-498.
- Lindell, A. K., & Kidd, E. (2011). Why right-brain teaching is half-witted: A critique of the misapplication of neuroscience to education. *Mind, Brain, and Education*, *5*(3), 121-127.
- Littlewood, W. (2009). Process-oriented pedagogy: facilitation, empowerment, or control. *ELT Journal*, *63*(3), 246-254.
- Logic Express (version 8) [Computer software]. Cupertino, CA: Apple Inc.
- Luck, S. J. (2005). *An introduction to the event-related potential technique*. Cambridge, MA: MIT Press.
- Lykken, D. T. (1982). Research with twins: The concept of emergensis. *Psychophysiology*, *19*(4), 361-372.
- Lykken, D. T., McGue, M., Tellegen, A., & Bouchard, T. J. (1992). Emergenesis: Genetic traits that may not run in families. *American Psychologist*, *47*(12), 1565.

- Lynn, S., & Rhue, J. (1986). The fantasy-prone person: Hypnosis, imagination, and creativity. *Journal of Personality and Social Psychology, 51*, 404-408.
- MacKinnon, D. (1978). *In search of human effectiveness: Identifying and developing creativity*. Buffalo, NY: Creative Education Foundation.
- Martella, R. C., Nelson, J. R., Morgan, R. L., & Marchand-Martella, N. E. (2013). *Understanding and interpreting educational research*. New York, NY: Guilford Press.
- Martindale, C. (1999). Biological bases of creativity. In R. Sternberg (Ed.), *Handbook of creativity* (pp. 137-152). New York, NY: Cambridge University Press.
- Martindale, C., & Dailey, A. (1996). Creativity, primary process cognition, and personality. *Personality and Individual Differences, 20*, 409-414.
- Martindale, C., & Hasenfus, N. (1978). EEG differences as a function of creativity, stage of the creative process, and effort to be original. *Biological Psychology, 6*(3), 157-167.
- Martindale, C., & Hines, D. (1975). Creativity and cortical activation during creative, intellectual, and EEG feedback tasks. *Biological Psychology, 3*, 71-80.
- Martindale, C., Hines, D., Mitchell, L., & Covello, E. (1984). EEG alpha asymmetry and creativity. *Personality and Individual Differences, 5*(1), 77-86.
- Marzban, C., Illian, P. R., Morison, D., & Mourad, P. D. (2013). Within-group and between-group correlation: Illustration on noninvasive estimation of intracranial pressure. Retrieved from:  
[http://faculty.washington.edu/marzban/within\\_between\\_simple.pdf](http://faculty.washington.edu/marzban/within_between_simple.pdf)

- McCrae, R. R. (1987). Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology*, 52(6), 1258-1265.
- McCrae, R. R. (1994). Openness to experience: Expanding the boundaries of Factor V. *European Journal of Personality*, 8(4), 251-272.
- Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, 69, 220-232.
- Mendelsohn, G. (1976). Associative and attentional processes in creative performance. *Journal of Personality*, 44, 341-369.
- Muijs, D. (2011). *Doing quantitative research in education with SPSS* (2<sup>nd</sup> ed.). Thousand Oaks, CA: Sage.
- Nardone, P. (1997). *The experience of improvisation in music: A phenomenological psychological analysis*. Unpublished PhD dissertation, Saybrook Institute, University of Michigan, Ann Arbor: UMI.
- Nelson, B., & Rawlings, D. (2007). Its own reward: A phenomenological study of artistic creativity. *Journal of Phenomenological Psychology*, 38 (2), 217-255.
- Neuroscan (2003). Offline analysis of acquired data (SCAN 4.3–Vol. II, EDIT 4.3).[Software Manual]. El Paso, TX: Compumedics Neuroscan .
- Nichols, R. C. (1978). Twin studies of ability, personality and interests. *Homo*, 29(3), 158-173.
- Osborn, A. (1953). *Applied imagination* (Rev. ed.). New York, NY: Scribner's.
- Ostendorf, F., & Angleitner, A. (1994). Reflections on different labels for Factor V. *European Journal of Personality*, 8(4), 341-349.

- Passer, M. W., Smith, R. E., Atkinson, M. L., Mitchell, J. B., & Muir, D. W. (2003). *Psychology: Frontiers and applications*. Boston, MA: McGraw-Hill Ryerson.
- Penke, L. (2003). Creativity: Theories, prediction, and etiology. *Unpublished diploma thesis, University of Bielefeld*.
- Peterson, J. B., & Carson, S. (2000). Latent inhibition and openness to experience in a high-achieving student population. *Personality and Individual Differences, 28*(2), 323-332.
- Peterson, J. B., Smith, K. W., & Carson, S. (2002). Openness and extraversion are associated with reduced latent inhibition: Replication and commentary. *Personality and Individual Differences, 33*(7), 1137-1147.
- Petsche, H., Kaplan, S., Von Stein, A., & Filz, O. (1997). The possible meaning of the upper and lower alpha frequency ranges for cognitive and creative tasks. *International Journal of Psychophysiology, 26*(1-3), 77-97.
- Pfurtscheller, G. (1999). Quantification of ERD and ERS in the time domain. *Handbook of Electroencephalography and Clinical Neurophysiology, 6*, 89-105.
- Pfurtscheller, G., & Aranibar, A. (1977). Event-related cortical desynchronization detected by power measurements of scalp EEG. *Electroencephalography and Clinical Neurophysiology, 42*, 817-826.
- Pfurtscheller, G., Stancak, A., & Neuper, C. (1996). Event-related synchronisation (ERS) in the alpha band - an electrophysiological correlate of cortical idling: A review. *International Journal of Psychophysiology, 24*, 39-46.
- Plomin, R., DeFries, J. C., McClearn, G. E., & Rutter, M. (1997). *Behavioral genetics*. New York: Freeman.

- Plucker, J. A., & Makel, M. C. (2010). Assessment of creativity. In Kaufman, J., Sternberg, R. (Ed.), *The Cambridge handbook of creativity* (pp. 48-73). New York, NY: Cambridge University Press.
- Posner, M. (1994). Attention: The mechanism of consciousness. *Proceedings of the National Academy of Sciences, 91*, 7398-7403.
- Rawlings, D. (1985). Psychoticism, creativity and dichotic shadowing. *Personality and Individual Differences, 6*(6), 737-742.
- Rawlings, D., Twomey, F., Burns, E., & Morris, S. (1998). Personality, creativity, and aesthetic preference: Comparing psychoticism, sensation seeking, schizotypy, and openness to experience. *Empirical Studies of the Arts, 16*(2), 153-178.
- Ray, W. J., & Cole, H. W. (1985). EEG alpha activity reflects attentional demands, and beta activity reflects emotional and cognitive processes. *Science, 228*(4700), 750-752.
- Razumnikova, O. (2007). Creativity related cortex activity in the remote associates task. *Brain Research Bulletin, 73*, 96-102.
- Reis, S. M., & Renzulli, J. S. (1991). The assessment of creative products in programs for gifted and talented students. *Gifted Child Quarterly, 35*(3), 128-134.
- Reznikoff, M., Domino, G., Bridges, C., & Honeyman, M. (1973). Creative abilities in identical and fraternal twins. *Behavior Genetics, 3*(4), 365-377.
- Rippon, G. (2006). Electroencephalography. In C. Senior, T. Russell, & M. Gazzaniga (Eds.), *Methods in mind* (pp. 237-262). Cambridge, MA: MIT Press.
- Runco, M. A. (1986a). The discriminant validity of gifted children's divergent thinking test scores. *Gifted Child Quarterly, 30*, 78-82.

- Runco, M. A. (1986b). Divergent thinking and creative performance in gifted and nongifted children. *Educational and Psychological Measurement*, 46, 375-384.
- Runco, M. A. (1989a). The creativity of children's art. *Child Study Journal*, 19, 177-189.
- Runco, M. A. (2008). Commentary: Divergent thinking is not synonymous with creativity, *Psychology of Aesthetics, Creativity, and the Arts*, 2(2), 93-96.
- Runco, M. A., & Albert, R. S. (1985). The reliability and validity of ideational originality in the divergent thinking of academically gifted and nongifted children. *Educational and Psychological Measurement*, 45, 483-501.
- Runco, M. A., & Basadur, M. (1993). Assessing ideational and evaluative skills and creative styles and attitudes. *Creativity and Innovation Management*, 2(3), 166-173.
- Sanei, S., & Chambers, J. A. (2007). *EEG signal processing*. Hoboken, NJ: John Wiley & Sons.
- Sauseng, P., Klimesch, W., Doppelmayr, M., Pecherstorfer, T., Freunberger, R., & Hanslmayr, S. (2005). EEG alpha synchronization and functional coupling during top-down processing in a working memory task. *Human Brain Mapping*, 26(2), 148-155.
- Schneider, W., Eschman, A., and Zuccolotto, A. (2001). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools, Inc.
- Shirley, D. A., & Langan-Fox, J. (1996). Intuition: A review of the literature. *Psychological Reports*, 79(2), 563-584.
- Simonton, D. K. (1975). Creativity, task complexity, and intuitive versus analytical problem solving. *Psychological Reports*, 37(2), 351-354.



- Solso, R. L. (2001). Brain activities in a skilled versus a novice artist: An fMRI study. *Leonardo*, 34(1), 31-34.
- Stayte, S. A. (1977). *Incidental learning creativity and schizophrenia* (Unpublished doctoral dissertation). University of London, London, England.
- Sternberg, R. J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press.
- Sternberg, R. (1986). *Intelligence applied: Understanding and increasing your intellectual skills*. San Diego, CA: Harcourt, Brace, Jovanovich.
- Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 3-15). New York, NY: Cambridge University Press.
- Taylor, D. W. (1960). Thinking and creativity. *Annals of the New York Academy of Sciences*, 91(1), 108-127.
- Taylor, C. W., & Ellison, R. L. (1966). *Alpha biological inventory*. Salt Lake City, UT: Institute for Behavioral Research.
- Tierney, P., & Farmer, S. M. (2002). Creative self-efficacy: Its potential antecedents and relationship to creative performance. *Academy of Management Journal*, 45(6), 1137-1148.
- Torrance, E. P. (1972) Can we teach children to think creatively? *Journal of Creative Behavior*, 6, 114-143.
- Torrance, E. (1974). *Torrance Tests of Creative Thinking: Norms-technical manual*. Bensenville, IL: Scholastic Testing Service.

- Torrance, E. P. (1988). The nature of creativity as manifest in its testing. In R. J. Sternberg (Ed.), *The nature of creativity* (pp. 43-75). New York: Cambridge University Press.
- Treffinger, D. J., & Poggio, J. P. (1972). Needed research on the measurement of creativity. *The Journal of Creative Behavior*, 6(4), 263-267.
- Von Stein, A., & Sarthein, J. (2000). Different frequencies for different scales of cortical integration: From local gamma to long range alpha/theta synchronization. *International Journal of Psychophysiology*, 38(3), 301-313.
- Wallach, M. A. (1971). *The intelligence/creativity distinction*. New York: General Learning Press.
- Wallach, M. A. (1976). Tests tell us little about talent. *American Scientist*, 64(1), 57-63.
- Wallach, M. A., & Kogan, N. (1965). Modes of thinking in young children: A study of the creativity-intelligence distinction. New York: Holt, Rinehart, & Winston.
- Waller, N. G., Bouchard, T. J., Jr., Lykken, D. T., Tellegen, A., & Blacker, D. M. (1993). Creativity, heritability, familiarity: Which word does not belong? *Psychological Inquiry*, 4(3), 235-237.
- Ward, L. M. (2003). Synchronous neural oscillations and cognitive processes. *Trends in Cognitive Sciences*, 7(12), 553-559.
- Wild, C. (1965). Creativity and adaptive regression. *Journal of Personality and Social Psychology*, 2, 161-169.

## APPENDICES

## Appendix A: Ethics Approval Form.



Western  
Research

Research Ethics

Use of Human Participants - Ethics Approval Notice

Principal Investigator: Prof. Marc Joanisse  
 File Number: 104532  
 Review Level: Delegated  
 Protocol Title: Musical improvisation in adults  
 Department & Institution: Social Science Psychology, Western University  
 Sponsor:  
 Ethics Approval Date: November 13, 2013 Expiry Date: December 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

Document Name	Comments	Version Date
Revised Western University Protocol	Received Dec 5 2013. Increase sample size from 20 to 45	2013/12/05

This is to notify you that The University of Western Ontario Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the applicable laws and regulations of Ontario has granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above.

This approval shall remain valid until the expiry date noted above assuming timely and acceptable responses to the NMREB's periodic requests for surveillance and monitoring information.

Members of the NMREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the NMREB.

The Chair of the NMREB is Dr. Riley Hinson. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Signature 

Ethics Officer to Contact for Further Information

 Grace Kelly	 Vikki Tran	 Mina Mekhaal	 Erika Basile
--	---	--	---

This is an official document. Please retain the original in your files.

## Appendix B: Recruitment Poster.



Western  
UNIVERSITY · CANADA

### ***Volunteers are Required to Participate***

**in a study of musical improvisation**

**This study aims to investigate how musical improvisation affects consciousness state. You must be over the age of 18 and be right-handed.**

**This study will take place at the Brain and Mind Institute at Western in the Natural Sciences Centre.**

**If you are interested or would like more information, please contact us at the address below.**

**You will be compensated \$20 for your time.**

## Appendix C: Letter of Information.



### Letter of Information

Title of Research Project: Musical Improvisation in Adults

Investigators:

Joel Lopata, Ph.D student  
 Elizabeth Nowicki, PhD  
 Marc Joanisse, Ph.D.

[REDACTED] ([REDACTED])  
 [REDACTED] ext. [REDACTED] ([REDACTED])  
 [REDACTED] ext. [REDACTED] ([REDACTED])

Information about the study:

The study will investigate musical improvisation and how it is related to activity in the brain. You are being asked to participate in this research because you are a musician with at least some proficiency playing a piano/keyboard, with the ability to improvise, who is between the ages of 18 and 85. To be included in this study you must be right handed, and have no history of neurological disorder. During this study we will examine your brain activity as you play three different pieces of music, and also as you see pictures of a few items. You will be fitted with a cap that contains sensors specially designed to monitor your brain activity using an electroencephalogram (EEG). Sensors will also be placed on your cheeks, forehead, and nose. Following this, gel will be inserted into each sensor.

The main task will involve listening to, playing back, and improvising over three short standard pieces of music. The second task will involve naming uses for common items and indicating your responses orally. Prior to completing each musical task you will be given the opportunity to practice on a keyboard and we will make sure you feel comfortable with the musical progressions. The study will take 1.5 to 2 hours, and you will be compensated \$20 for participating.

We hope to discuss the findings of the study at scientific conferences and intend to publish them in a professional journal. We expect the study to add to psychologists' understanding of improvisation, creativity, and learning. In the future, this information

might help educators to create or incorporate better techniques for teaching improvisation and creativity.

Comfort and Safety:

This is a non-invasive technique and there are no known risks to participating in this study. However, the cap is tight fitting and may lead to some slight discomfort. The electrode gel is easily washed out of the hair, and we will provide you with shampoo and clean towels to do so at the end of the experiment.

Please note participation is voluntary and that you are free to stop participating in the study at any time without consequence. You will still receive compensation if you decide to stop participating.

You will receive written feedback at the end of the experiment, at which point any additional questions you may have will be answered.

Confidentiality:

All data collected will be coded numerically to ensure your confidentiality. Furthermore, no information that might identify you will be shared with anyone outside the research team. This consent form will be kept separate from the data collected. Data will be kept in a locked room, and viewed only by the researchers. The data will be destroyed after 5 years (or sooner at your request by contacting Mr. Lopata or Dr. Nowicki). If we publish results of the study, your name will not be used, nor will your data be identifiable (only data averaged across will be published).

## Appendix D: Musical Improvisation Performance Questionnaire (MIPQ).

Music Adjudication Questionnaire

Participant # \_\_\_\_\_

### Innovation

1. How unique is this improvisation compared to the melody?

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

2. How unique is this improvisation compared to what you'd expect someone to play over these chords?

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

3. How unique/novel is this improvisation overall?

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

### Technical Ability

4. How much command of the instrument is displayed?

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

5. How complex are the musical thoughts/ideas?

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

6. How theoretically advanced is this improvisation?

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

### Musicality

7. How enjoyable or fulfilling are the tonal and rhythmic sequences played?

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

8. How much personal style is present in the improvisation?

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

9. How clear are the musical ideas in this improvisation?

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

### Overall impression

10. How would you rate the quality of this improvisation overall?

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

## Appendix E: Participant Information Questionnaire.

### Participant Information Questionnaire

Date of Participation (dy/mn/yr): \_\_\_\_\_

Birth Date: \_\_\_\_\_

Sex:    M    F

Musical instruments played:

---



---

Years/Months of musical experience: \_\_\_\_\_

Years/Months of improvisational experience: \_\_\_\_\_

Music education:

    Formal programs or courses: \_\_\_\_\_

    Private lessons: \_\_\_\_\_

    Self-taught: \_\_\_\_\_

    Other: \_\_\_\_\_

Formal improvisation education:

    Formal programs or courses: \_\_\_\_\_

    Private lessons: \_\_\_\_\_

    Self-taught: \_\_\_\_\_

    Other: \_\_\_\_\_

History of Musical Performance: \_\_\_\_\_

---



---



History of Improvisational Performance: \_\_\_\_\_

---

---

---

---

Would you describe yourself as a classical musician, a jazz musician, both, or neither?

---

**Appendix F: Alternate Uses Test Item Images.**

Participants were shown images and given the opportunity to generate ideas about their possible uses for three minutes per item.









### Appendix G: Music Charts.

## C-BLUES (16-DAK)

C-BLUES (16-DAK)  
[C] [F] [G]

[C]

[F] [C]

[G] [F]

[C] [G]

[END] [G] [C]

[G] - I - V - II - IV progression

Example #2

[G] [D]

[Am] [C]

[G] [D]

[Am] [C]

# D-MODAL

Always/Always

[D<sup>9</sup>]

[Am<sup>9</sup>]

[Dm<sup>9</sup>]





## Appendix H: Debriefing Form.

### Debriefing Form Musical Improvisation in Adults

This experiment is part of an exploration into how people's states of consciousness change during musical improvisation. Research suggests that when you are creative your state of consciousness changes, and that this may be indicated by changes in brain waves (Dietrich, 2004; Martindale, 1999; Fink et al., 2009). However, to date this has only been explored using functional magnetic resonance imaging (fMRI), or during improvised dance and visual art using EEG. Thus, what is not clear is whether a person's state of consciousness changes when they are improvising musically compared to when they are playing in a rote manner. It is also not clear as to which of predisposition toward creativity, or improvisational experience plays a greater role in the ability to enter this proposed state of consciousness. This is a critical question to understanding whether people can learn to be creative, and may provide insight into the value of teaching creativity in music and in general.

In this study you came up with ideas for uses of common household items and filled out a questionnaire regarding your music experience. You also listened to, played back, and improvised over three musical passages while we monitored your brain responses using an electroencephalogram (EEG). We expect that EEG imaging will show increased alpha activity during musical improvisation, and not during a rote musical task. We also predict that a person's creativity will be associated with brain wave activity. These findings may suggest that creativity may be defined as a unique state of consciousness, and that all people can learn to be more creative with experience and education.

If you have any further questions regarding this research or theories of improvisation and creativity, feel free to contact Joel Lopata at [REDACTED] or [REDACTED], or Dr. Elizabeth Nowicki at [REDACTED] ext. [REDACTED] or [REDACTED], or Dr. Marc Joannis at [REDACTED], ext. [REDACTED] or [REDACTED].

This study has been approved by the Peer Ethics Review Board in the Department of Psychology at Western University. If you have any questions about your rights as a research subject, you should contact the Director of the Office of Research Ethics at Western: [REDACTED] or [REDACTED].

#### References:

- Dietrich, A. (2004). The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, 11 (6), 1011-1026.
- Fink, A., Graif, B., & A.C., N. (2009). Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers. *NeuroImage*, 46, 854-862.
- Martindale. (1999). Biological Bases of Creativity. In R. Sternberg, *Handbook of Creativity* (pp. 137-152). New York: Cambridge University Press.

## CURRICULUM VITAE

**Name:** Joel A. Lopata

**Post-secondary Education and Degrees:** York University  
Downsview, Ontario, Canada  
1996-2000 B.F.A.

The University of Western Ontario  
London, Ontario, Canada  
2007 B.Ed. w/ Honours

The University of Western Ontario  
London, Ontario, Canada  
2008-2010 M.Ed.

The University of Western Ontario  
London, Ontario, Canada  
2010-2014 Ph.D.

**Honours and Awards:** Canadian Centre for Inclusive Education Research Award  
2010

Western Graduate Student Teaching Award (2013)  
2013

Western Graduate Research Scholarship (WGRS)  
2010-2014

**Related Work Experience** Research Assistant  
The University of Western Ontario  
2009-2014

Lecturer  
The University of Western Ontario  
2013-2014

**Publications:**  
Lopata, J. A., Nowicki, E. A. (2014). Pre-service Teacher Beliefs on the Antecedents to Bullying: A Concept Mapping Approach. *Canadian Journal of Education*, 37(4), 1-25.