DESIGNING FOR THE SUBCONSCIOUS: A NEUROIS STUDY OF PRIMING AND IDEA GENERATION IN ELECTRONIC BRAINSTORMING

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There has been extensive research on electronic brainstorming (EBS) over the past two decades, yet little is known about how best to design technology to enhance overall team performance. This dissertation seeks to open a new door in EBS design: designing a system for the individual's subconscious. Before effective design interventions can be developed, the cognitive underpinnings of individual-level EBS interactions must be elucidated. These studies provide insight into the core of this issue by examining the neurophysiological correlates of the ideation process, specifically using electroencephalography (EEG), electromyography (EMG), and skin conductance to examine priming-induced changes in cognition and emotion during an EBS session. Furthermore, it extends prior research on the use of priming to enhance EBS performance, creating new design guidelines for EBS systems that are designed for the user's subconscious. The findings show that achievement priming changes cognition in areas of the brain related to creativity which correspond with increases in idea fluency and creativity. While the implications of this study will be directly applicable to design of EBS technology, future studies can examine the use of priming in other collaboration tools. There may also be implications for the design of other forms of technology. The use of NeuroIS to more fully understand information processing in teams can also enhance the collaboration literature, in that it can illuminate individual cognition limitations in team interactions and enhance our understanding of which aspects of team interactions have the biggest "bang for their buck" from a cognitive standpoint. These findings provide several avenues for future research.

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INTRODUCTION

Introduction

Virtual teams are common in today's organization and have been the primary focus of much research. Much of the research has targeted design interventions meant to improve team-level processes, but few design interventions have been aimed at alleviating the cognitive limitations of individual team members, which may have important impacts on team performance (Heninger et al. 2006). Recent studies have attempted to understand the role of individual cognition in team processes (Kolfschoten 2011a; Kolfschoten and Reinig 2012). Some studies have influenced subconscious cognition through priming (Dennis et al. 2013; Postmes et al. 2001), while others have examined conscious cognitive processes such as dual-task interference (Heninger et al. 2006). These studies have found that the cognitive processes of individual team members are inextricably linked to overall team performance.

One form of collaboration technology used by virtual teams is electronic brainstorming (EBS). EBS system design was influenced heavily in the 1990s by research on process gains and losses, aimed at enhancing team processes not individual cognition (e.g., Dennis et al. 1996; Nunamaker et al. 1996). Current design guidelines for EBS systems remain similar to those of twenty years ago: a text-based chat tool that provides increased parallelism and anonymity compared to face-to-face discussions (Briggs et al. 2009; Mametjanov et al. 2011).

This dissertation opens a new door in EBS design: designing a system for the individual's subconscious. More specifically, I created a system to enhance an individual team member's cognition by activating a subconscious desire to "achieve," thus improving the idea generation performance of the overall team. My research builds on recent research that attempted to influence subconscious cognition to enhance EBS performance (see, Dennis et al. 2013; Postmes et al. 2001). In Dennis et al (2013), findings show that supraliminal priming of the concept "achievement" substantially increases fluency and creativity of ideas generated in a brainstorming session.

Supraliminal priming is a behavioral intervention intended to activate an individual's internal mental representations (Bargh and Chartrand 2000). A variety of concepts and emotional states have been evoked using supraliminal priming, such as success, motivation, positive affect, negative affect, and mindfulness (Bargh and Chartrand 2000). Dennis et al (2013) found the use of supraliminal, scrambled-sentence priming of the concept "achievement" at the *individual level* improves EBS performance of the *entire virtual team*. The effect size of priming was as large as the effect size observed in using EBS technology itself (Dennis et al. 2013). However, in this study they used traditional, "a priori" priming, which requires an artificial 8-minute priming session prior to the brainstorming session.

The first goal of this dissertation is to better understand how priming influences the behavior of individual team members participating in an EBS discussion. There are two potential routes that need to be further examined. One route is that achievement priming affects individual cognition, which in turn influences individual behavior and overall team performance. The second route is through emotion, namely that achievement priming influences individual emotion which in turn influences individual behavior and team performance. Neither of these routes are mutually exclusive and it is possible that priming influences individual behavior through an interaction of *both* of the routes.

In Dennis et al. (2013) the authors propose that individual cognition is affected through priming. However, this study did not propose a potential role of emotion on individual behavior. In addition, the authors did not discuss the processes by which the change in cognition occurred. This dissertation provides a clear understanding of how priming influences cognition and emotion, giving a holistic picture of how priming influences individual behavior. This understanding also helps illuminates how to create effective primes that enhance team performance. To do this, I used of a combination of electroencephalography (EEG) and psychophysiological measures, including electromyography (EMG) and skin conductance, which have been shown to be effective measures of cognitive and emotional responses. These tools measure how an individual's ideation process is affected by being exposed to priming.

The second goal of this dissertation is to design an EBS tool that primes an individual with the subconscious goal of "achievement" concurrently as they work on a brainstorming task. Previous studies that have used priming utilize it in an "a priori" fashion. That is, they prime an individual *before* the task commences. The ability to prime an individual in real-time as they complete a team task has not been explored in the literature. This study aims to *integrate* priming into the EBS tool so that individuals can be primed as they complete the EBS task (which I refer to as "concurrent" priming).

Research Questions

This dissertation addresses three research questions and designs an EBS tool that enhances individual behavior through emotional and/or cognitive mechanisms, thereby improving idea production during an EBS session. The first research question examines the route through which a priori achievement priming affects idea generation performance, specifically which emotional and/or cognitive responses are induced through priming. For the second research question there are two parts. First, I develop a new type of prime that is integrated into the EBS tool. The second part of the research question addresses behavioral outcomes, mainly whether exposure to a concurrent, achievement prime increases the fluency and quality of ideas produced. The concurrent prime is expected to work through a similar cognitive and emotional route as the a priori prime, yet its time course may be different. Thus, the second research question examines whether concurrent priming acts through an emotional and/or cognitive route to enhance idea generation performance. The third research question addresses whether the changes in ideation induced through priming occur because the prime is achievement-oriented or because the prime is positive in emotional valence and arousal. Therefore, the research questions are:

RQ1: In a priori priming, does the prime affect idea generation performance through an emotional and/or cognitive route during an EBS session?

RQ2a: Does concurrent priming of achievement increase the fluency and quality of ideas produced during an EBS session?

RQ2b: In concurrent priming, does the prime affect idea generation performance through an emotional and/or cognitive route during an EBS session?

RQ3: In concurrent priming, do the changes in ideation occur from the achievement-oriented nature of the images or the positive valence and arousal of the images?

Dissertation Overview

This dissertation includes three studies. The first study has two primary goals. First, it replicates findings of a priori, achievement priming and increased EBS fluency and creativity found in Dennis et al. (2013). Second, and more importantly, it opens up the “black box” of individual behavior, examining the precise emotional and cognitive changes that occur following exposure to an a priori prime. These changes are achievement priming-induced alterations in neurophysiology and psychophysiology that affect the subsequent EBS session. The second study examines the effect of a newly designed concurrent prime, integrated into the EBS tool, and its effect on both behavioral (fluency/creativity), emotional (arousal/valence), and cognitive (attention/working memory) outcomes. The third study examines whether the changes in ideation (i.e., behavior and cognitive/emotional) are created by concurrent priming being achievement-oriented or by the prime being positive in both emotional valence and arousal.

Expected Contributions

The main contribution of this dissertation is to alter EBS design in shifting our focus to designing systems that enhance individual cognition. Previous design of EBS systems have focused on creating more efficient team processes and leveraging process gains afforded by technology. This dissertation provides an argument for shifting this logic to a new stage of EBS design, creating systems that reach better outcomes by helping the individual reach their ideation maxima.

This dissertation also opens a new door in collaboration research, namely designing collaboration tools that enhance individual cognition leading to improved team performance. While the direct contribution of these studies provides a new set of design principles for EBS systems, it is not limited to the EBS artifact. Findings of enhanced performance in an EBS setting also provide fruitful areas of study for designing other types of collaborative technology for the subconscious, such as video conferencing, decision support systems, and social networking tools.

Another contribution is to the emergent NeuroIS literature. NeuroIS is an area of information systems research, wherein neuroimaging techniques are used to elucidate IS problems. In this context, the use of NeuroIS, and specifically EEG in this proposal, provides an opportunity to examine information processing directly. The use of EEG to understand neurophysiological changes in cognition and emotion has the potential to uncover what happens in the brain during an EBS task after an individual has been primed.

A final contribution of this dissertation provides a better understanding of the emotional and cognitive underpinnings of priming-influenced ideation that help researchers understand how priming influences individual cognition during an EBS session. A further understanding of the mechanism through which priming influences individual behavior enables more effective development of primes, strengthening our ability to design systems for the subconscious. These contributions, taken together, further the collaborative and NeuroIS research streams.

LITERATURE REVIEW

Overview of priming

Priming has been shown to change both our cognition and emotion (Bargh and Chartrand 2000; Zajonc 1984). Priming is the activation of internal mental representations in an attempt to influence subsequent behavior (Bargh and Chartrand 2000). Priming is traditionally implemented by giving a series of stimuli first (thus, “a priori”), then measuring subsequent behavior on a task of interest. Once an individual’s mental representations have been activated by the priming stimuli, subsequent behavior is influenced. Priming has been shown to influence both cognition and emotion (Murphy and Zajonc 1993). The depth of priming literature is expansive, with researchers using it to influence everything from affecting purchase intentions (Yi 1990) to slowing a participant’s walking speed (Bargh et al. 1996) to cultivating rude behavior (Shariff and Norenzayan 2007) to sparking motivation to succeed on a task (Bargh et al. 2001).

Priming stimuli can take many forms, however, two common forms are with pictures or words. There are many different ways individuals can be primed. However, the three studies in this proposal use a form of semantic priming. Semantic priming is designed to activate semantic networks within the brain and works by activating associations closely related to a concept. Generally, this is done by using pictures or words related to a concept (Carr et al. 1982). The brain is organized into networks based on the associations one makes during prior experiences (Martin and Chao 2001). Semantic networks develop as we begin to interact with the world and form a basis of semantic memory that is interconnected with our previous associations of core objects, concepts, or beliefs.

Priming research began with a study on creativity that described the tendency of individuals to use prior notions of how objects should be used to complete tasks (Duncker 1945). These prior notions inhibited one's creativity. However, when an individual witnessed a novel use of an object immediately preceding a creativity task, he or she was more likely to use a novel approach in completing his or her task (Duncker 1945). Initially referred to as "perceptual readiness," the term "priming" was later coined by Segal and Cofer (1960) in reference to a phenomenon where participants exposed to words in one task were more likely to use those words in subsequent tasks (Cofer 1967). In later studies, the idea of priming was developed to describe the activation of mental representations to influence future individual responses (Bargh and Chartrand 2000).

There are two predominant ways to deliver priming: subliminal ("below threshold") and supraliminal ("above threshold"). Subliminal priming involves brief presentation of a stimulus, on the order of milliseconds, followed by a perceptual mask

(Bargh and Chartrand 2000). In this case, the stimulus is presented quickly and the participant is not consciously aware of it. In contrast, with supraliminal priming, the participant is consciously aware of the stimulus, but is not aware of its intent. The common feature of both subliminal and supraliminal priming is that the participant is unaware that the stimulus is activating mental representations (Bargh and Chartrand 2000). This dissertation focuses on supraliminal priming as prior research has shown priming effects generated by supraliminal priming last for several minutes after the priming session. A discussion of the duration of supraliminal priming effects is discussed in later sections.

Priming and individual behavior

Priming research has shown that priming influences individual behavior through emotional response and changes in cognition (Murphy and Zajonc 1993). Cognitive processes such as categorization, recognition, and recall have all been shown to be influenced by evoking mental representations of the constructs (Bargh 2002; Bargh and Chartrand 2000). Once constructs become activated in the mind, its accessibility in memory is heightened (Srull and Wyer 1980). Concepts and constructs that have become accessible can subconsciously direct cognitive processes such as selective attention or information retrieval from long-term memory (Yi 1990). Emotional (or affective) response are typically viewed as a subjective experience that can be characterized by two parameters: valence and arousal (Cacioppo et al. 2004). Cognitive response, on the other hand, consists of specific mental processes, such as memory, attention, feature identification, and categorization that involve estimates of sensory and perceptual qualities (Murphy and Zajonc 1993).

In emotion, valence refers to the direction of behavioral activation associated with an emotion. Valance describes a response to a stimulus that results in approach behavior (i.e., appetitive/positive) or avoidance behavior (i.e., aversive/negative) (Lane et al. 1999). Valence was initially thought of as existing on a bipolar continuum, yet, more recently, research has shown that positive and negative valence may exist on separate continuums each ranging from “low” to “high” (Lang et al. 2005). The implication of the “dual system” view of valence is that individuals can have varying levels of positive and negative emotion occurring simultaneously. Researchers have found that both positive and negative valence can be effectively measured by levels of activation and deactivation of the corrugator supercilii muscle (Larsen et al. 2003). Arousal, on the other hand, is believed to exist on a single continuum, which indicates how awake or reactive an individual is to stimuli (Bolls et al. 2001; Lane et al. 1999). In sum, emotion is conceptualized as having two dimensions: the valence (i.e., positive or negative) and arousal (i.e., intensity) of the emotion.

Most priming research on emotions has focused on the effect of priming on positive and negative emotional valence, rather than arousal (Zemack-Rugar et al. 2007). Priming effects have been found exposing individuals to emotionally laden stimuli (Chartrand et al. 2006). Repeated exposure to words with positive valence has been found to create a positive emotional state, which in turn influences an individual’s subsequent behavior (Chartrand et al. 2006). Similarly, repeated exposure to words with negative valence creates a negative emotional state, also influencing the individual’s subsequent behavior (Chartrand et al. 2006). In some emotional priming research, researchers have been able to alter mood states in clinically depressed individuals, though the altered state is transient and reverts back to baseline after a period of time (Fresco et al. 2006; Segal and Ingram 1994).

This study will use semantic priming to better understand the route through which achievement priming affects ideation performance. In semantic priming, the *association* between words is more important in activating mental representations than the word itself (Lucas 2000). For example, priming the word popcorn is likely to activate semantic networks associated with eating and semantic networks associated with movies because most people are aware that popcorn is popular in movie theaters. Thus if we prime the word popcorn and then ask individuals to name celebrities, they would be more likely to name movie stars than rock stars because the semantic network associated with movies is active in working memory and the semantic network associated with music is not. As one might expect, activation of semantic networks through priming is not permanent and decays over time (Bargh and Chartrand 2000).

In a classic study not involving priming, participants read a series of behaviors with instructions either to form an impression of the actor or to memorize the information. The researchers found that the individuals that had been given the impression-formation goal were able to recall more behaviors and had greater organization of the material in memory than those given a goal only to memorize the information (Hamilton et al. 1980). In an extension of this study using priming, individuals were not given conscious instructions, but were primed with synonyms of memorization (e.g., retain, hold) or evaluation (e.g., judge, evaluate). The findings were identical with individuals given the impression-formation priming being able to recall more behaviors with greater organization of the material in memory (Chartrand and

Bargh 1996). This research produced an important implication: the effect of priming an individual resulted in the same behavior as giving the individual direct instructions.

It would be erroneous to assume that emotional or cognitive reactions to priming are mutually exclusive, rather emotions and cognition often interact with both having been shown to influence behavior (Zajonc 2000). In addition, research has shown that defining primes as purely affective or purely cognitive oversimplifies the actual influence of the prime (Zajonc 2000). In actuality, there is likely a change in emotion and a change in cognition that results from most primes. Therefore, it is more reasonable to assume that cognition and emotions are mutually *related* in priming.

More recently, priming research has focused on using primes to intentionally influence human behavior. The key to developing a successful prime lies in optimizing its ability to awaken mental representations or emotions related to the construct. A wide array of constructs have been activated through this mechanism. In one of the most well-known priming experiments, individuals played a scrambled sentence word game, wherein there were words related to stereotypes of elderly people (e.g., *Florida*, *old*, *lonely*, *dependent*) (Bargh et al. 1996). Once individuals had played this game, they were thanked for their participation and left the experiment. Unbeknownst to them, there was a confederate in the hallway outside the experimental room that timed their walk to the elevator. The researchers found that individuals exposed to the “elderly” prime walked more slowly than individuals exposed to a neutral prime designed to have no effect (Bargh et al. 1996). The individuals primed with words related to our stereotypes of the elderly took 15% longer to walk down the hallway than those not primed with the elderly stereotype (Bargh et al. 1996).

In another experiment, individuals were exposed to words related to politeness (e.g., *respect*, *patiently*, *cordially*, *considerate*) (Bargh et al. 1996). In a separate treatment, individuals were primed with words related to rudeness (e.g., *aggressively*, *bold*, *rude*, *brazen*) (Bargh et al. 1996). The participants played a scrambled sentence word game. The participant was instructed to contact the experimenter upon completion of the word game. When the participant finished the game, they opened the door to the experiment room to find the experimenter in a discussion with a confederate posing as another participant. Individuals primed with politeness interrupted the experimenter and the confederate 18% of the time, whereas those primed with rudeness interrupted 64% of the time. Individuals receiving a neutral prime designed to have no effect, interrupted 38% of the time, indicating that the politeness priming reduced the rate of interruptions by 20% and the rudeness prime increased the rate of interruptions by 26% (Bargh et al. 1996).

To summarize, priming is the use of stimuli to activate internal mental representations of a concept. It has been done in a variety of contexts, but typically involves the use of an a priori priming session, followed by behavioral measurement. Priming has been shown to be effective in evoking stereotypes, mindsets, emotions, differing cognitive states, and behaviors. In addition, priming studies have traditionally examined individual behavior as the outcome measures (Bargh and Chartrand 2000). Only recently have studies begun to examine the effect of individual priming on team interactions (Dennis et al. 2013; Postmes et al. 2001). More discussion of priming and team behavior will be covered below.

Electronic brainstorming

Extensive research on brainstorming has been conducted over the last half century (see, for review, Isaksen 1998). Since it was first described in 1954, brainstorming has been utilized by organizations to generate alternatives for both simple and complex problems (Isaksen 1998; Osborn 1954). A team's primary objective in idea generation is to produce creative ideas that can be further evaluated and implemented. One key assertion made in Osborn (1954) is that groups of individuals can generate more ideas if team members concentrate on producing whatever ideas occur to them, while simultaneously avoiding evaluation of the ideas. Osborn further asserted that individuals brainstorming in a group would generate more ideas than the same number of individuals working separately, known as nominal group brainstorming (Osborn 1954). In organizations, teams exist in a variety of different formations (e.g., formal versus informal, large versus small), yet idea generation is a prevalent group activity in all configurations (DeSanctis and Gallupe 1987).

Teams can engage in brainstorming in a variety of ways (e.g., verbal, electronic, nominal). Verbal brainstorming has been used for more than a half century as a way to improve individual brainstorming performance (Dennis and Valacich 1993). A verbal brainstorming exercise should have four goals: (a) producing a large quantity of ideas, (b) criticism must be ruled out, (c) freewheeling (wild/weird ideas) must be accepted and (d) combination and improvisation on ideas should be encouraged (Osborn 1954).

There is an extensive body of literature on idea generation in virtual teams (see, Dennis and Wixom 2002), establishing that virtual teams outperform face-to-face teams in idea fluency and creativity (Briggs et al. 1997; Dennis and Valacich 1999). Idea fluency is generally measured as the total number of unique ideas generated by a group.

Creativity of ideas can be conceptualized on different dimensions, such as novelty, workability, relevance, and specificity (Dean et al. 2006). Goals of virtual teams can vary with some teams requiring high idea fluency and other teams requiring only a few highly creative ideas (Connolly et al. 1990).

Electronic brainstorming (EBS) involves the use of technology (e.g., e-mail, browser based systems, text-based chat) to facilitate the brainstorming process (Gallupe et al. 1992). It has been shown that the use of EBS results in better idea generation performance than verbal interaction (Dennis and Wixom 2002). EBS captures the best elements of verbal brainstorming by allowing group members to share and build on ideas (Gallupe et al. 1991). EBS also minimizes the effect of production blocking and offers increased anonymity, which have been shown to increase brainstorming performance (Nunamaker et al. 1991). In addition, EBS systems allow individual team members to scroll back through previously generated ideas at any point (Dennis and Valacich 1993).

More recently, EBS research is examining individual characteristics and cognition as important factors influencing the success of EBS in group processes (Antunes and Ferreira 2011; Kolfschoten 2011b). For example, EBS performance is affected by group member characteristics such as domain knowledge, cognitive ability, personality type and creative skill (Paulus and Yang 2000). Similarly, group performance has also been shown to be influenced by the interface of the EBS tool (Shepherd et al. 1995). However, little research has examined interface-design factors that can *enhance* individual cognition in virtual teams.

Priming and team EBS

One key consideration in integrating the research on priming and EBS is identifying the type of priming that will influence EBS performance. Many studies have focused on influencing human behavior, with researchers finding that priming can influence how individuals approach problems (Bargh et al. 1996; Bargh et al. 2001). In one such experiment, researchers used a word search puzzle to prime the concept of achievement (Bargh et al. 2001). In this study, individuals received either priming semantically related to achievement (e.g., *compete, win, succeed*) or neutral words (e.g., *ranch, carpet, shampoo*). Individuals primed with achievement performed better in subsequent tasks than individuals exposed to the neutral prime (Bargh et al. 2001). Bargh et al. (2001) argues that achievement priming improves performance by activating semantic networks related to achievement. These active networks motivate behavior by creating a subconscious desire to achieve, thus influencing performance.

Individual motivation to perform a task is a function of the individual's perception of the importance of that task and the expectancy of success (Wigfield and Eccles 1994). If one can positively influence either the perception of importance or expectancy of success, motivation to perform the task should increase (Wigfield and Eccles 1994). I argue that achievement priming works by activating the semantic networks associated with success. I assert that when the semantic networks associated with success are activated in memory by a priming stimulus, the individual subconsciously experiences an increase in the expectancy of success for the subsequent task. This increase in the expectancy of success causes motivation to increase, which in turn improves performance.

In a study applying achievement priming to the EBS context, researchers found that priming achievement increased idea fluency and creativity by approximately 30% (Dennis et al. 2013). This study found that priming individuals improved performance of the overall team, thus extending achievement priming to team behavior. The authors specifically discuss how changes in individual cognition might be one route through which ideation performance was effected (Dennis et al. 2013). Priming likely affects subsequent performance by changing an individual's motivation to perform the task.

NeuroIS

NeuroIS is an emergent sub-field of information systems that draws upon neuroscience literature on cognition and emotion to inform IS research (Dimoka et al. 2011). There are a variety of NeuroIS tools (e.g., fMRI, EEG, NIRS), each having their own strengths and weaknesses. These tools allow IS researchers to better examine the underlying information processing that occurs as individuals interact with technology (Dimoka et al. 2011). The use of cognitive neuroscience tools enables novel examination of fundamental IS problems that surveys, lab experiments, and field studies are unable to resolve. One such study, has the IS conceptualization of "trust," indicating that trust and distrust are fundamentally different concepts, residing in different areas of the brain (Dimoka 2010). The research agenda of NeuroIS includes localizing neural correlates of IS constructs, capturing mental processes, and complementing existing sources of IS date with brain data (Dimoka et al. 2011).

The physiological effects of priming on emotion and cognition have been well documented in the literature, though most studies utilize subliminal priming and relatively small time windows (see, for example, Arndt et al. 2001; Bernat et al. 2001). In one study, individuals were exposed to positive and negative words and EEG and facial EMG were used to examine the responses. The study found changes in facial EMG and EEG that coincided with the valence of the word that had been shown (e.g., positive changes in affect were observed following positive words) (Bernat et al. 2001). These findings provide support for priming working through an emotional route. Similarly, priming has shown to induce changes in cognition (Holcomb and Neville 1990). In one study, changes were observed in EEG measurement of the N400, a neurophysiological response that is closely tied to attention and cognitive load, after exposure to a semantic prime (Holcomb and Neville 1990).

In this dissertation, I use three tools to examine changes in cognition (specifically working memory and attention) and emotion induced by priming during an EBS session. For changes in emotion, I use a combination of psychophysiological and neurophysiological measurements. Psychophysiological measurements have been found to be useful in both the measurement of emotional valence and arousal (Bolls et al. 2001). Specifically, for changes in valence, I use facial EMG, while changes in arousal will be measured by skin conductance. Changes in cognition will be measured using EEG, a neurophysiological tool.

STUDY ONE: A PRIORI PRIMING

Introduction to a priori priming

The first study within this dissertation focuses on discovering the cognitive and emotional changes induced by "a priori" priming. "A priori" priming is priming delivered *before* a task to influence behavior on that task. Previous research has established that "a priori" achievement-oriented priming influences the fluency and creativity of ideas generated in subsequent EBS sessions (Dennis et al. 2013; Postmes et al. 2001). However, these studies do not examine the cognitive and emotional underpinnings in the individual that drive the changes in ideation fluency and creativity. This study addresses the first research question, which examines whether a priori priming affects ideation performance through an emotional and/or cognitive route during an EBS session. Formally stated,

RQ1: In a priori priming, does the prime affect idea generation performance through an emotional and/or cognitive route during an EBS session?

Theory and hypotheses

In Dennis et al. (2013) the authors did not discuss potential changes in emotion, induced by priming that might also influence ideation performance. The achievement priming condition of their study likely influences individual (and thus team) performance through two routes: emotion and cognition. The priming words utilized in their study were achievement-related and, therefore, were expected to activate semantic networks related to achievement (i.e., influence cognition). Similarly, the priming words were also positive in valence and high in arousal. Since the individuals were exposed to words of positive valence and high arousal repeatedly,Chartrand et al. (2006) would predict the words to have an effect on the participant's emotions as well.

The authors further theorized that increased individual idea production is likely to have a direct effect on the group output and performance. This study showed that increases in idea fluency and creativity were as large as using the EBS technology itself (Dennis et al. 2013). The first study of this dissertation will attempt to replicate this finding and extend it to examine the cognitive underpinnings of the expected effect.

The first hypotheses in this study seek to replicate these findings, while the hypotheses in later sections focus on the specific emotional and cognitive changes induced by achievement priming. Therefore, achievement priming is hypothesized to increase the idea fluency during a subsequent EBS task. Thus,

Hypothesis 1a: A priori priming of the concept "achievement" will increase idea fluency during an EBS session.

In addition to increasing the overall fluency of ideas, the semantic prime is expected to increase the creativity of the ideas through the same theoretical mechanism as increasing idea fluency. In Dean et al. (2006), idea creativity is conceptualized as a multi-dimensional construct, consisting of four dimensions. These four dimensions are novelty, workability, relevance, and specificity (Dean et al. 2006). Idea creativity is generally conceptualized as a count of the number of "highly creative" ideas *or* a total creativity score across all ideas. In Dennis et al. (2013), priming was found to increase the overall creativity of ideas generated in an EBS session. In this study, a priori, achievement priming is expected to increase the creativity of ideas generated during an EBS task. Thus,

> *Hypothesis 1b: A priori priming of the concept "achievement" will increase idea creativity during an EBS session.*

3.2.1. *A priori priming and time*

Priming effects are transient in nature and decay after a period of time (Bargh and Chartrand 2000; DeCoster and Claypool 2004). As time elapses after the priming stimuli, cognitive changes become less pronounced, resulting in dissipation of the priming effect (DeCoster and Claypool 2004). In fact, a priming effect decay function has been described in the literature (Higgins et al. 1985). This study found that there is a fixed, maximal level of activation that is reached during the priming manipulation, which slowly dissipates after the prime is removed (Higgins et al. 1985). There has been some debate in the literature over whether priming effects decay at a linear or exponential rate. The notion is that, after exposure to a prime, the effect on cognition dissipates at a given rate determined by a host of factors like frequency or intensity of the prime (Higgins et al. 1985). As a priming effect decays, the networks representing the primed construct become less activated and eventually the behavior is no longer influenced (Higgins et al. 1985).

This study examines the effect of priming over time in addition to examining the overall effect outlined in Section 2.4. While the overall effect outlined in Section 2.4 is a replication of prior work, Dennis et al. (2013) did not examine idea generation *over time* during the EBS session. Examination of the time course of idea generation will help elucidate when the a priori priming effect exerts its greatest influence. Since a priori priming is known to decay, it is likely that the greatest productivity gains occur during the initial stages of an EBS session immediately following the prime. As a result, I hypothesize that the performance differences in achievement priming (as compared to neutral priming) will be the strongest in the first half of the EBS task. There is some debate in the literature whether the decay function in a priori priming results in either a linear or exponential rate of decay (DeCoster and Claypool 2004; Higgins et al. 1985). Regardless, of the slope of the decay function, performance on latter stages of the task will be influenced by priming effect decay. Therefore, performance on the late stages of the task will result in idea generation that is no different than neutral priming. Thus,

> *Hypothesis 2a: A priori priming of the concept of "achievement" will result in greater idea fluency than neutral priming during the first half of an EBS session.*

> *Hypothesis 2b: A priori priming of the concept of "achievement" will result in no different idea fluency than neutral priming during the last half of an EBS session.*

Idea creativity has also been shown to be influenced by achievement priming (Dennis et al. 2013). It is expected that after exposure to an a priori prime, creativity during an EBS session will also decrease as the time unfolds. During the beginning of the task, creativity will likely be different between the achievement and neutral priming conditions, whereas, in the latter parts of the task, priming is likely to become similar between the achievement and neutral priming conditions as the priming effect decays. Therefore, I hypothesize:

> *Hypothesis 3a: A priori priming of the concept of "achievement" will result in greater idea creativity than neutral priming during the first half of an EBS session.*

> *Hypothesis 3b: A priori priming of the concept of "achievement" will result in no different idea creativity than neutral priming during the last half of an EBS session.*

3.2.2. *Psychophysiological correlates of cognition*

Cognitive changes were measured using EEG. EEG is a neurophysiological measurement of post-synaptic electrical potentials on the surface of the scalp (Gibbs and Gibbs 1941). Electrodes are placed on specific locations on the scalp and collect the summation of synchronized activity from underlying pyramidal neurons lying near the surface of cortex. The measure at each electrode location is then compared to a reference electrode located elsewhere on the scalp (Harmon-Jones and Peterson 2009). The recorded oscillations of brain activity at each electrode are complex waveforms that can be decomposed into simple waveforms of different periodicity at varying amplitudes. EEG researchers often are interested in five frequency bands: delta (< 4 Hz), theta (4-8Hz), alpha (8-13Hz), beta (13-20Hz), and gamma (>20) (Harmon-Jones and Peterson 2009).

I will focus on the alpha band because of the inverse relationship between alpha frequency amplitude and attention, wherein lower levels of alpha represent higher levels of attention. When the brain is at rest, alpha rhythms result from the synchronization of underlying neural activity, which is indicative of an "idling" process. When the brain is active, desynchronization of these neurons occurs, resulting in decreases in alpha frequency detected at the scalp which is referred to as "alpha blocking" (Andreassi 2007;

Potter and Bolls 2011). Better performance has been found as a result of increased activity (measured as alpha blocking) (Hoptman and Davidson 1998).

When developing hypotheses for this study, it was first necessary to deconstruct the cognitive processes associated with the study task—text-based team brainstorming—in order to identify regions where alpha blocking would be expected. Information will be presented visually during the discussion via text displayed on a computer screen. Thus, if an individual observes and pays attention to incoming textual information, decreases in alpha could be expected in the occipital region of the brain, known to pertain to initial processing of visual stimuli (Beaumont 1983). In the occipital lobe initial, high-level categorization of the information occurs (i.e., "this is a word" vs. "this is a face") (Beaumont 1983). After this, language-related information is relayed to language processing brain regions such as Wernicke's and Broca's areas for further assessment (Gevins and Smith 2000; Watkins and Paus 2004).

Working memory plays a central role in cognition (Baddeley 1992). It encapsulates both what many consider "short-term memory" and attention. Therefore, working memory is pivotal for both information processing and brainstorming, responsible for encoding information from the environment and retrieving information from long-term memory in order to make sense of it (Baddeley 1992; Conway and Engle 1994; Welsh et al. 1999). A useful computer analogy for understanding working memory is that it represents the brain's RAM, storing of information currently undergoing processing but limited in its capacity (D'Esposito 2007). Working memory is most heavily associated with the frontal areas of cortex, namely Dorsolateral Prefrontal Cortex (DLPFC) (D'Esposito et al. 1995). However, it is important to note that neural networks distribute working memory to multiple areas of cortex. Changes in activity in the DLPFC indicate changes in working memory load and attention (Wager et al. 2004). In EEG, attenuation of the alpha rhythm over DLPFC indicates increases in working memory load (Gevins et al. 1997). Cognitive load in working memory (in the frontal and temporal regions of the brain) is reduced when irrelevant information is presented, as less information needs to be maintained for subsequent recall (Lavie 2005).

In this study, use an a priori prime. The prime is expected to have a similar effect on cognition measured as greater alpha attenuation in the frontal cortices after exposure to the achievement-oriented prime. Given the close relationship between frontal alpha-wave activity and attention, I hypothesize:

> *Hypothesis 4: A priori priming of the concept of achievement, as compared to a neutral prime, will increase attention during ideation in an EBS session.*

3.2.3. ***Psychophysiological correlates of emotion***

As discussed in Section 2.2, emotion has two distinct components: valence (i.e., direction) and arousal (i.e., intensity) (Cacioppo et al. 2004). Both positive and negative valence can be measured using facial EMG. The electrical signals generated by the facial muscles can be measured by placing electrodes over the specific muscle groups. The most common muscle groups measured for emotional valence are the corrugator supercilli muscle (Bolls et al. 2001). The corrugator muscle, often called the “frown” muscle, is located above the brow off the bridge of the nose. When the corrugator contracts, the muscle moves the brow downward and inward (Fridlund and Izard 1983).

The use of the corrugator supercilli muscle in the measurement of valence was validated using both pictures (Lang et al. 1993) and words (Wexler et al. 1992). When participants were exposed to negative pictures or words, the corrugator muscle contracted

(Lang et al. 1993; Wexler et al. 1992). These findings have been shown to be robust even when more complex stimuli are used, such as radio advertisements (Bolls et al. 2001), television programs (Potter et al. 2006), and video games (Ravaja et al. 2008). More recently, the corrugator supercilli muscle has been shown to *deactivate* when an individual experiences *positive* valence (van den Hoogen et al. 2012; van Reekum et al. 2011).

In most priming experiments, the valence of the words differs between priming manipulations (Bargh 2002; Bargh and Chartrand 2000). In the context of achievement priming, words surrounding achievement generally have high positive valence. Repeated exposure to positive words has shown to increase positive valence, while repeated exposure to negative words has been shown to increase negative valence (Bradley and Lang 1994; Kensinger and Schacter 2006). Therefore, I expect achievement priming to result in increased positive valence. Increased positive valence can be measured by the corrugator supercilli muscle becoming relatively more *deactivated* following exposure to the prime. Therefore,

> *Hypothesis 5a: A priori priming of the concept of "achievement" will result in a physiological response that indicates more positive valence than neutral priming during ideation in an EBS session.*

Emotional arousal will be measured using electrodermal activity (EDA), specifically skin conductance will be measured off the plantar surface of the foot. Increases in sympathetic nervous system activation result in increased skin conductance (Lykken and Venables 1971). Dense populations of sweat glands are located in the hand and foot. These locations are considered the optimal locations to obtain EDA (Lykken and Venables 1971).

Semantic priming often uses stimuli that also have high arousal. For example, in Dennis et al. (2013), the words in the achievement priming condition had significantly higher arousal than the neutral priming condition. Repeated exposure to words that have been rated as high in arousal has been shown to increase an individual's arousal (Bradley and Lang 1994; Kensinger and Schacter 2006). In one study, emotional words high in arousal were shown to amplify the priming effects resulting from repeated exposure to the words (Thomas and LaBar 2005). These highly-arousing words were shown to increase an individual's arousal independently from the valence attributes of the word (Thomas and LaBar 2005). The mechanism through which increased arousal occurs is related to autonomic nervous system activation, specifically increases in sympathetic nervous system activation (Bradley et al. 2008). The result of this increased activation manifests in increased skin conductance, pupil size, and heart rate (Bradley et al. 2008). Exposure to an achievement prime is expected to increase sympathetic nervous system activation (i.e., increased arousal), resulting in increased skin conductance in subsequent ideation during an EBS session. Therefore,

> *Hypothesis 5b: A priori priming of the concept of "achievement" will result in a physiological response that indicates increased arousal than neutral priming during ideation in an EBS session.*

3.2.4. *Changes in cognition and emotion over time*

As discussed in Section 2.5, priming effects decay over time. Since priming effects decay over time, the physiological changes occurring in the body will diminish over time as well. Due to the transient nature of the priming effect, it is expected that any changes in emotion or cognition will be most apparent in the beginning stages of the task and will return to baseline in the latter stages of the task. For emotion, changes in valence and arousal will be apparent early on the task, and return to baseline as the priming effect decays. A similar result is expected in cognition, most changes in cognition will occur in the beginning of the task with a gradual return to baseline as the task unfolds. Therefore, I hypothesize:

Hypothesis 6a: A priori priming of the concept of "achievement" will result in more positive valence during ideation in the first half of an EBS session when compared to neutral priming.

Hypothesis 6b: A priori priming of the concept of "achievement" will result in no different positive valence during ideation in the last half of an EBS session when compared to neutral priming.

Hypothesis 7a: A priori priming of the concept of "achievement" will result in increased arousal during ideation in the first half of an EBS session when compared to neutral priming.

Hypothesis 7b: A priori priming of the concept of "achievement" will result in no different arousal during ideation in the last half of an EBS session when compared to neutral priming.

Hypothesis 8a: A priori priming of the concept of "achievement" will result in greater attention, as measured by alpha attenuation in the frontal cortices, during ideation in the first half of an EBS session when compared to neutral priming.

Hypothesis 8b: A priori priming of the concept of "achievement" will result in similar attention, as measured by alpha attenuation in the frontal cortices, during ideation in the last half of an EBS session when compared to neutral priming.

Study One: A Priori Priming Methodology

3.3.1. *Participants*

Sixty students were recruited from an introductory business course at a large, state university. The course consisted of sophomores and juniors, and participants received extra credit for completing the study. Information on an individual's age, gender, and grade level was collected via demographic questionnaire. Demographic variables were obtained to provide average age and gender distribution. Age ranged from 19 to 25. The average age of the participants was 19.53. Thirty-three participants (55%) were male and 27 participants were female (45%). Fifty participants reported being right handed, 8 reported being left handed, and 2 reported being ambidextrous.

3.3.2. *Tasks*

This study used two 12-minute electronic brainstorming (EBS) tasks based on prior literature (Dennis et al. 2013; Dennis and Valacich 1994). One task was generating ideas to increase tourism within a state and the other task was generating ideas on reducing pollution. The participants were instructed to generate as many ideas as possible, building off of the ideas of others in the "team."

However, participants did not actually interact with other team members; rather they were deceived into believing they were working with a team. They used a team simulator that played a 12-minute prepared script. The script was derived from a real five-member, 15-minute EBS discussion. The script was utilized to provide experimental control, creating consistency between the individuals in the EEG study. Simulators have been utilized in many prior studies in both EBS and decision-making tasks (Garfield et al. 2001; Heninger et al. 2006). They have been shown to be useful for researchers studying individual behavior in team interactions by controlling for the variance in interactions between different teams (Heninger et al. 2006).

In a similar manner to text-based discussion tools, the simulator provided two onscreen windows. The top window contained the comments from other "team members" and the comments submitted by the participant to the group, while the bottom window provided space for participants to type their ideas. Once the participant hit the "enter" key or clicked "submit," their idea moved to the top window and was displayed to the rest of the team. A scroll bar appeared on the right of the top window, and the text will move up as new ideas were generated (either from the simulated group or the participant). The participant were told that other team members were located across campus.

3.3.3. *Treatments*

This study was a repeated measures experiment using a priori priming with pictures. Each participant received two within subject treatments: achievement priming and neutral priming. The within subject treatments were fully counterbalanced to control for task or priming order effects. The participants viewed a picture for 10 seconds then answered follow-up questions on how positive and negative the picture made them feel as well as how aroused the picture made them feel. In each priming condition, the participant viewed and rated 20 images. Priming research has shown that priming someone with a concept for five minutes leads to a priming effect of approximately ten minutes (Bargh and Chartrand 2000), and past research has shown no carry-over effects of priming from one treatment to another in repeated measures studies (Dennis et al. 2013).

The achievement priming treatment will be designed to prime the concept of "achievement," while the neutral priming treatment will be designed to have no effect. In the achievement priming treatment, pictures were chosen to relate to the concept of "achievement". The achievement priming condition for the a priori priming consisted of a set of 20 images oriented towards the concept of "achievement," while the neutral priming condition consists of 25 images designed to have no effect. Five placebo images were included in the achievement priming condition to ensure some variance in emotional arousal and valence of the images. The images for the achievement and neutral priming conditions were rated by a group of students on achievement, arousal, and valence. Examples of the achievement and neutral images are provided in Appendix C of this document. The achievement-oriented images significantly differed from neutral images on achievement rating by students ($t(58) = 7.87$, $p < .001$) (for a full summary of results see Appendix A). Arousal was rated on a scale from 1 (low arousal) to 9 (high arousal), and valence is rated from 1 (negative) and 9 (positive). The neutral images were moderate in arousal (M = 4.64, S.D. = 0.39) and moderate in valence (M = 5.32, S.D. = 0.49). The achievement priming images had higher arousal (M = 5.14, S.D. = 0.41) and more positive valence (M = 5.47, S.D. = 0.61). The achievement priming images significantly differed from the neutral priming words on both arousal ($t(58) = 4.41$, $p < .001$) and valence ($t(58) = 3.75$, $p < .001$).

3.3.4. *Dependent Variables*

The dependent variables of this study consisted of both behavioral measures and physiological measures.

3.3.4.1. Behavioral Measures

The primary behavioral dependent measure is idea generation performance. Idea generation performance can be conceptualized in a variety of ways. In this study, performance is conceptualized in two ways: number of unique ideas generated and the creativity of ideas generated. Two raters independently analyzed the ideas generated from a subset of 20% of the total participants. The two raters independently identified the number of unique ideas in the transcript. The raters then came together and identify the number of concordant ideas (i.e., ideas agreed upon by both raters as being unique ideas for that transcript). Inter-rater reliability was established by counting the number of ideas the raters agreed upon across 20% of the chat transcripts and dividing by the total number of ideas identified as "potential unique ideas" by the raters (i.e., calculated by (1-(number of agreements between coders / total codings). Inter-rater reliability for number of unique ideas generated was 95.2%.

The second behavioral measure was idea creativity. A master idea list was generated from all ideas mentioned by the participants. After the master idea list had been created, the creativity of each idea will be assessed. While there are many ways to conceptualize creativity, this study employed the approach outlined by Dean et al. (2006). Dean et al. (2006) conceptualizes creativity as a multi-dimensional construct, consisting of 4 unique dimensions: novelty, workability, relevance, and specificity. Three of the dimensions are used in this study. The specificity dimension was omitted because the use of a master idea list (a generalized list of similar ideas across groups) removed unique wording used by the participant, and it is the unique wording of the idea that is used to assess the specificity of the idea.

Each of the dimensions of creativity consists of two sub-dimensions. Novelty is comprised of originality and paradigm relatedness. High originality indicates the idea is both rare and ingenious or imaginative (Dean et al. 2006). Each idea was ranked on a scale from 1 (not original) to 4 (very original). Paradigm relatedness was the degree to which an idea relates to the currently prevailing paradigm and indicates the idea has the ability to be transformational and germinal to solving the problem at hand (Dean et al. 2006). For example, in a brainstorming task involving increasing tourism in Arizona, an idea highly unrelated to current paradigms would be: "advertising Arizona as having ocean front property after California falls into the ocean." Paradigm relatedness is scored on a scale of 1 (paradigm preserving) to 4 (paradigm breaking).

For the workability dimension of creativity the two sub-dimensions are implementability and acceptability. Acceptability was measured by determining the degree to which an idea can be successfully adopted by a society or organization (Dean et al. 2006). Acceptability was scored on a scale of 1 (not acceptable) to 4 (acceptable, violates no societal/organizational norms). The second sub-dimension of workability was implementability. Implementability describes how easily an idea can be realized (Dean et al. 2006). It was scored on a scale from 1 (totally infeasible) to 4 (easy to implement at low cost).

The final dimension of creativity that was measured in this study is relevance, which consists of the sub-dimensions applicability and effectiveness. Applicability describes how well the idea relates to the stated problem (Dean et al. 2006). It was measured on a scale from 1 (does not produce a useful outcome) to 4 (solves the identified problem that is directly related). The second sub-dimension of relevance was effectiveness or the degree to which the idea will solve the problem. It was measured on a scale from 1 (solves an unrelated problem, would not work on current problem even if you could do it) to 4 (reasonable and will solve the stated problem without regard for workability).

There are several ways of calculating creativity (e.g., calculating a total creativity score, counting the number of good ideas, etc.) (Reinig et al. 2007). In this study, I measure creativity as a count of the number of ideas rated as highly creative (Reinig et al. 2007). To obtain the ideas high in creativity, only the ideas coded as 3 or above will be counted on each dimension. Then the total number of highly creative ideas will be generated for each participant based on novelty, workability, and relevance dimensions. Each participant will receive a separate novelty, workability, and relevance score. Two raters rated 20% of the ideas generated on each of the six dimensions used in the study. Inter-rater reliability was calculated as (1-(number of agreements between coders / total codings. Inter-rater reliability was established at 89.6% for the ratings of idea quality with no sub-dimension having less than 87% reliability on the quality ratings by the two raters.

3.3.4.2. Physiological Measures

There are three physiological measures utilized in this study: cortical attention, autonomic arousal, and emotional valence. These were operationalized using neurological and psychophysiological measures. The primary physiological measure in this study was cortical attention, operationalized using neurophysiological measures (i.e., EEG alpha wave). EEG measures were collected using a 14-channel headset (Emotiv Systems, San Francisco, CA, USA) with electrodes dispersed over the scalp along the 10-20 system (Herwig et al. 2003) (see Figure 1). The Emotiv system is a low-density electrode EEG device that has been shown to collect a veracious signal of underlying cortical activity. The signal obtained has been shown to be as good as larger high-density systems. Even though it is a low-density system, research has shown the Emotiv system detects neurophysiological signals equivalent to high-density, expansive EEG arrays (Badcock et al. 2013).

EEG, as a neurophysiological technique, is the measurement of the electrical signals present at the surface of the scalp. An EEG system is capable of measuring the relatively small electrical signals produced in the superficial areas of the underlying cortices. EEG is widely regarded as having the highest temporal resolution of all the neuroimaging techniques, capable of accurately measuring electrical signals on the order of milliseconds. Over time, these electrical signals form complex wave patterns or oscillations. Different oscillations have been shown to be related to various aspects of cognition. For example, the alpha wave, an oscillation with a frequency of 8-13Hz, has been shown to be closely related to attention (Başar et al. 2001). Higher levels of alpha activity on the scalp relates to lower levels of attention. The alpha wave has also been shown to be location-specific with the presence of alpha waves in various locations of cortex being related to different cognitive processes. For example, alpha waves over left frontal cortex are related to cognitive load, working memory, and attention, while alpha waves over the occipital lobe being closely related to visual attention (Başar et al. 2001).

The EEG device consists of electrodes, which connect with the scalp surface via felt pads saturated with saline solution. Generally, EEG devices measure electrical activity in relation to the deviance from another pair of sensors on the scalp. For the Emotiv device, the reference electrodes are located at P3 and P4 over the inferior, posterior parietal lobule (Herwig et al. 2003). All other channels will be measured in relation to the electrical activity present at these locations, sampled at 128Hz. Impedances will be verified and data will be collected using Emotiv TestBench Software Version 1.5.0.3, which can export data into comma-delimited format for subsequent analysis in Matlab. A detailed overview of the EEG data cleansing and analysis process is provided in Appendix B.

Second, skin conductance was used as a measure of autonomic arousal in the participant, operationalized as skin conductance level measured between two electrodes on the surface of the skin. Skin conductance has been used in experimental research for decades and has been shown to be related to a variety of concepts related to arousal (Lykken and Venables 1971). Increases in skin conductance indicate increased autonomic arousal and further indicate the level of attention or excitation of the participant (Lykken and Venables 1971). Generally, skin conductance has a time-lag of 3 to 4 seconds from stimulus onset. Therefore, changes in skin conductance in this study were measured during the time window of 2 to 6 seconds after an ideation process has started (e.g., 3 to 6 seconds after the first keystroke that is followed by the participant submitting an idea to the group). Skin conductance was measured with 8mm bipolar AG/AGCL electrodes that were filled with electrically neutral gel and adhered to the planar surface of foot after lightly hydrating it with distilled water. A Coulbourn Instruments (Whitehall, PA, USA) skin conductance coupler delivered .5V to the planar surface and conductance will be sampled by a Coulbourn AD/DA board at 125Hz using VPM software version 12.8 (Cook 2010).

Third, emotional valence was operationalized as the relative activation of the corrugator supercilli muscle group. Corrugator and zygote EMG were measured using a pair of mini (4mm) reusable AG/AGCL electrodes filled with electrolyte gel placed above the subject's left eye after dead skin cells had been removed by a skin prep pad containing rubbing alcohol and pumice. The bipolar corrugator measures was collected using a Coulbourn bioamplifier with high pass filters set at 8Hz. The full wave signal is rectified and then contour integrated online at a time constant of 100ms prior to sampling.

3.3.5. *Procedure*

Participants completed the experimental procedure individually after providing informed consent approved by the university's Institutional Review Board. The experiment took place in an individual lab room at a research institute. The entire research session lasted approximately 90 minutes. The surveys presented in the experiment were controlled by MediaLab software (Jarvis 2010). The simulator was be presented using MatLab software.

Participants were seated in a high back chair to minimize movement. They used a standard keyboard and mouse. The protocol began with a 10-minute series of handedness and demographic questionnaires. The experimenter then explained the procedure for attaching the physiological electrodes and fitting the EEG apparatus, answering any questions posed by the participant. Readings for the EMG and EEG measures to assure appropriate levels of impendence.

Participants were be instructed to view the pictures and rate how the pictures made them feel; all participants in the same group received the same priming treatments, either achievement or neutral. In addition, task order and treatment order were fully counterbalanced and participants were randomly assigned to one of the task/priming treatment orders. Participants then worked on the first EBS task for twelve minutes. Next they completed a short personality survey to serve as a "distractor" between treatments. Participants repeated these same steps (priming game, idea generation) for the second priming manipulation and task. The participants were then debriefed and the session concluded.

In total, the EEG apparatus was only on the participants for approximately 45 minutes, during which the electrodes remained damp with the saline solution. Impedance values for each cranial location remained acceptable for the duration of the experiment. Markers were inserted into the data by the simulation software, indicating when the subject entered an idea into the chat simulator. This allowed for synchronization between the EBS session, EEG and EMG systems. When the discussion simulation completed, the experimenter removed all physiological data collection sensors. Participants then completed the post-experiment questionnaire. Finally, they were debriefed, told of the deception, asked not to inform others of the deception, and thanked for their time.

3.3.6. *Manipulation Checks*

It was essential to ensure that participants perceived the simulator as a real team discussion. All participants completed post-session questionnaires that asked if they had noticed anything unusual about the team discussion. A variety of distractor questions (e.g., satisfaction with discussion, perceived effectiveness) were also included to better ensure that manipulation check question did not stand out. Participants that recognize they were not interacting with real people were removed from the study as failing the manipulation check. Seven of the 60 participants recognized they were interacting with a simulator and were removed from the analysis, leaving 53 participants in the study. This represents a 11.7% of individuals failing the manipulation check, which is in line with prior studies ranging to 10-15% of the subjects failing manipulation checks (Garfield et al. 2001; Heninger et al. 2006).

3.3.7. *Data Analysis*

3.3.7.1. EEG Data Cleaning and Preparation

EEG data were cleaned and analyzed using EEGLab Version 13.0.0.0 (Delorme and Makeig 2004). One limitation of EEG is that cortical bioelectrical activity is extremely small in magnitude when compared to muscle movements across the head. Therefore, participant movement introduces artifacts of high-frequency and magnitude into the EEG data. The most notorious of these is the ocular or “eye motion” artifact. These were removed using two methods: EEGLab probability calculations and visual inspection. The EEGLab artifact rejection algorithm uses deviations in microvolts greater than three standard deviations from the mean to reject specific trials. However, additional artifacts are also apparent to the trained eye, so visual inspection of trials is essential in artifact removal (Delorme and Makeig 2004). The number of trials varied based on the number of ideas generated by each individual in each EBS session. Using published guidelines (Delorme and Makeig) we rejected approximately 20% of the trials based on muscular artifacts.

In addition to trial-by-trial removal of artifacts, occasionally specific EEG channels must be rejected in an individual subject's data due to unacceptable impedance levels. This was done in the current study using an automatic impedance detection feature of EEGLab. Single channels were detected and removed from 1 participants prior to analysis. No subject had more than one channel rejected.

3.3.7.2. ICA Decomposition of EEG data

The first step of the EEG analysis was an Independent Components Analysis (ICA) at the individual level. A common problem in neuroimaging research results from the collection of large amounts of data which, based upon the Central Limit Theorem, become normally distributed. However, the brain is comprised of discrete patches of cortex that are very active at some points in time and relatively non-active at others (i.e., activity is not normally distributed across the scalp) (Onton and Makeig 2006). ICA overcomes this problem by taking this Gaussian data and rotating it until it becomes non-Gaussian, thereby isolating independent components contributing to the activitation.

Initially, an EEGLab ICA performs a Principal Components Analysis (PCA). At each electrode site the program assesses which of the other electrode sites account for the most variance in the signal. Taking these weighted values it then relaxes the orthogonality constraint of PCA to isolate individual components of activation (Onton and Makeig 2006). Each ICA component then represents a pattern of activation over the entire brain, not solely the activity present at a specific electrode. The number of independent components (ICs) depends on the number of electrodes in the dataset, as the algorithm is working in an *N*-dimensional space (where N is the number of electrodes). Most participants in the current study generated 14 distinct ICs, since our recording device had 14 electrodes. The participant with a single electrode removed from analysis due to poor impedance produced 13 ICs.

Finally, using the *K*-means component of EEGlab the independent components at the individual level were grouped into clusters of similar components generated *between* subjects. This was done using recommended procedures that clustered similar ICs according to their latency, frequency, amplitude, and scalp distribution (Delorme and Makeig). Eight clusters were generated and evaluated for the final analysis.

EEG measurement provides a plethora of data that can be decomposed using different analytical procedures. I chose to use Event Related Spectral Perturbation (ERSP) for its ability to model both time and frequency changes occurring in the ICs over the time window specified. Time-frequency analysis is especially appropriate for low-density EEG systems. The ERSP produces a latency-by-frequency image that shows mean changes in log power from some pre-specified baseline mean value (Makeig 1993). In this experiment we used the 1000ms *after* an idea had been generated as our baseline mean. I generated ERSPs that were during the ideation process (i.e., immediately before the subject entered an idea in the chat simulator). Therefore, the ERSPs were from 4000ms to 2000ms *before* the subject entered an idea into the chat simulator.

I generated ERSPs that included the alpha band frequency (8-13Hz), which is closely tied to attention and cognitive load (Klimesch et al. 1993; Onton et al. 2005). Decreases in log power over the latency window indicate increased attention during that timeframe. EEGLab provides statistical comparisons of ERSPs.

Study One: A Priori Priming Results

3.4.1. *Behavioral results*

The statistical analyses for the behavioral component of study one were completed in SPSS PASW Statistics 18.0. A repeated-measures GLM was used to examine differences between the achievement and neutral priming conditions.

3.4.1.1. Idea fluency

Individuals produced significantly more ideas with achievement priming pictures than the neutral priming pictures ($F(1,50) = 8.05$, $p = .007$). The effect size was small with a Cohen's *d* of 0.28. The order in which the group received priming treatments did not affect the number of unique ideas generated ($F(1,50) = 3.55$, $p = .065$), nor did the task order for the pollution and tourism task ($F(1,50) = 0.15$, $p = .705$). Therefore, Hypothesis 1a was supported.

3.4.1.2. Idea Creativity

Individuals produced a greater number of novelty ideas following the a priori achievement priming treatment than the neutral ($F(1,50) = 9.80$, $p = .003$). The effect size was medium with Cohen's $d = .403$. The order in which the participant received the priming conditions did not affect the number of novel ideas produced ($F(1,50) = .04$, $p = .837$), nor did the order in which he or she received the pollution or tourism task ($F(1,50) = .29$, $p = .596$).

Individuals produced a greater number of workable ideas following the a priori achievement prime than the neutral prime ($F(1,50) = 6.72$, $p = .012$). The effect size was small with a Cohen's $d = .278$. The order in which the participant received the priming conditions did not affect the number of workable ideas produced ($F(1,50) = 1.10$, $p = .300$), nor did task order ($F(1,50) = .40$, $p = .529$).

Individuals produced a greater number of relevant ideas following the a priori achievement prime than the neutral priming game (F(1,50) = 12.36, p = .001). The effect size was medium with Cohen's *d* = .400. The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,50) = .93, p = .341), nor did task order (F(1,50) = .008, p = .930).

The findings on novelty, workability, and relevance, taken together, provide full support for Hypothesis 1b. The a priori achievement prime significantly increases the creativity of ideas produced in subsequent EBS sessions.

Table 1.1 Means, standard deviations, and results of statistical analyses

		Achievement Prime		**Neutral Prime**		**F**	**p-value**
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**		
Number of Unique Ideas	53	12.13	5.18	10.75	4.49	8.05	0.007
Number of Novel Ideas	53	3.58	3.07	2.47	2.39	9.80	0.003
Number of Workable Ideas	53	11.21	5.36	9.89	4.06	6.72	0.012
Number of Relevant Ideas	53	10.60	4.80	8.92	3.54	12.36	0.001

3.4.2. *A priori priming and time*

3.4.2.1. Idea fluency and time

Individuals produced significantly more ideas in the achievement treatment compared to the neutral treatment during the first half of the EBS session (F(1,50) = 12.638, p = .001). The effect size was small with a Cohen's *d* = .21. The order in which the participant received the priming conditions did not affect the number of ideas produced in the first half of the EBS session (F(1,50) = .363, p = .550), nor did task order (F(1,50) = .191, p = .664). These findings support Hypothesis 2a and the a priori achievement priming effect appears to have an immediate influence on idea fluency. The means, standard deviations, and results are provided in Table 1.2.

In addition, individuals produced significantly more ideas in the achievement treatment compared to the neutral treatment during the last half of the EBS session ($F(1,50) = 8.045$, $p = .007$). The effect size was small with a Cohen's $d = .28$. The order in which the participant received the priming conditions did not affect the number of ideas produced in the last half of the EBS session ($F(1,50) = 3.547$, $p = .065$), nor did the task order ($F(1,50) = .145$, $p = .705$). Therefore, Hypothesis 2b was not supported, the priming effect generated by the a priori achievement prime persists longer than the first half of the EBS session. The means, standard deviations, and results are provided in Table 1.3.

In addition to the hypothesis tests, I also compared the first half achievement idea fluency against the last half of achievement with a post-hoc pairwise comparison. The number of ideas generated in the first half of an EBS session after the achievement prime did not significantly differ from the last half of ideas generated in an EBS session after the achievement treatment ($t(104) = 1.36$, $p = .176$). However, the number of ideas produced during the first half of the EBS session in the neutral treatment significantly differed from the number of ideas produced in the last half of the EBS session of the neutral treatment ($t(104) = 1.98$, $p = .05$). This indicates that a priori achievement priming produces a priming effect that persists longer than the neutral (i.e., placebo) prime.

3.4.2.2. Idea creativity and time

Individuals produced a greater number of novel ideas following the a priori achievement priming treatment during the first half of an EBS session when compared to neutral (F(1,50) = 117.04, p < .001). The effect size was medium with Cohen's *d* =.435. The order in which the participant received the priming conditions did not affect the number of novel ideas produced (F(1,50) = .21, p = .653), nor did the order in which he or she received the pollution or tourism task (F(1,50) = 2.36, p = .131).

Individuals produced a greater number of workable ideas following the a priori achievement prime during the first half of an EBS session when compared to neutral (F(1,50) = 166.34, p < .001). The effect size was small with a Cohen's *d* = .302. The order in which the participant received the priming conditions did not affect the number of workable ideas produced (F(1,50) = .54, p .466), nor did task order (F(1,50) = .066, p = .798).

Individuals produced a greater number of relevant ideas following the a priori achievement prime during the first half of an EBS session when compared to neutral (F(1,50) = 127.45, p < .001). The effect size was small with Cohen's *d* = .388 . The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,50) = .04, p = .847), nor did task order (F(1,50) = 3.14, p = .083). These findings support Hypothesis 3a. The means, standard deviations, and results are provided in Table 1.2.

Similarly, individuals produced a greater number of novel ideas following the a priori achievement priming treatment during the last half of an EBS session when compared to neutral (F(1,50) = 9.80, p = .003). The effect size was small with Cohen's *d* = .358. The order in which the participant received the priming conditions did not affect the number of novel ideas produced (F(1,50) = .043, p = .837), nor did the order in which he or she received the pollution or tourism task (F(1,50) = .29, p = .596).

Individuals produced a greater number of workable ideas following the a priori achievement prime during the last half of an EBS session when compared to neutral ($F(1,50) = 6.72$, $p = .012$). The effect size was small with a Cohen's *d* = .243. The order in which the participant received the priming conditions did not affect the number of workable ideas produced ($F(1,50) = 1.10$, $p = .300$), nor did task order ($F(1,50) = .40$, $p = .529$).

Individuals produced a greater number of relevant ideas following the a priori achievement prime during the last half of an EBS session when compared to neutral ($F(1,50) = 12.36$, $p = .001$). The effect size was medium with Cohen's *d* = .403. The order in which the participant received the priming conditions did not affect the number of relevant ideas produced ($F(1,50) = .93$, $p = .341$), nor did task order ($F(1,50) = .008$, $p = .930$). These findings do not support Hypothesis 3b and indicate that the achievement priming effect persists past the first half of the EBS session. The means, standard deviations, and results are provided in Table 1.3.

Table 1.2 Means, standard deviations, and results of priming time statistical analyses for first half of the EBS session

		Achievement Prime First Half		Neutral Prime First Half		F	p-value
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**		
Number of Unique Ideas	53	6.45	2.71	5.89	2.69	12.64	0.001
Number of Novel Ideas	53	2.09	1.58	1.47	1.25	117.04	< 0.001
Number of Workable Ideas	53	6.19	2.92	5.40	2.27	166.34	< 0.001
Number of Relevant Ideas	53	5.62	2.61	4.75	1.80	127.45	< 0.001

Table 1.3 Means, standard deviations, and results of priming time statistical analyses for last half of the EBS session

		Achievement Prime Last Half		Neutral Prime Last Half		F	p-value
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**		
Number of Unique Ideas	53	5.68	3.09	4.87	2.62	8.05	0.007
Number of Novel Ideas	53	1.49	1.53	1.00	1.19	9.80	0.003

Number of Workable Ideas	53	5.02	2.47	4.49	1.84	6.72	0.012
Number of Relevant Ideas	53	4.98	2.22	4.17	1.77	12.36	0.001

3.4.3. *Changes in Cognition*

3.4.3.1. Event-related Spectral Perturbation (ERSP) analysis

The *K*-means cluster analysis produced three neurological clusters of interest. These were selected initially according to the number of subjects and ICs represented in each cluster and were supported by visual inspection of the corresponding scalp maps. Scalp maps provide information as to the dispersion of activity within a frequency band across the scalp. Due to the idiosyncratic nature of neural activity within each participant, some individuals did not produce independent components in each cluster. One cluster, for example, contained data from 32 subjects, meaning 13 of the 45 usable EEG subjects did not produce neural responses statistically related to the others in the regions identified by the cluster. This may be explained by differences in brain lateralization and structure among participants in the study. Another possibility is the signal-to-noise ratio in the EEG signal is smaller than other types of bioelectrical activity. Participants which produced many muscular artifacts may have produced ICs that were predominated by the much larger variance created by these muscle movement (and not neural activity).

We set the statistical threshold at ($p < .05$) and corrected for multiple comparisons using the false discovery rate (FDR). FDR uses the approach of Benjamini & Hochberg (Benjamini and Hochberg 1995) to minimize Type I error with only a marginal loss of statistical power (see Appendix B for more information).

The first cluster is geographically distributed across the right frontal areas of cortex with a strong activation apparent in this region. This cluster contained data from

37 subjects and 50 ICs. This cluster appears to be highly localized to the right frontal lobe and is not geographically diverse (See Figure 1.1). Right frontal activation has been shown to be associated with creativity and divergent thinking on tasks (Carlsson et al. 2000; Razoumnikova 2000).

T-tests comparing the achievement prime and neutral prime are presented in Figure 1.1. After exposure to the achievement prime, individuals showed significant alpha attenuation (i.e., increased attention) (Panel 1) as compared to the neutral condition (Panel 2). Panel 3 shows areas where they significantly differed. Alpha band differences were detected between 4000ms and 2000ms before the subject entered ideas into the chat simulator. Furthermore, these changes were evident across the alpha frequency band (8-13Hz), showing greater cortical attention after the a priori achievement prime in this region when compared to the a priori neutral prime. This indicates increased cognitive activity in right frontal in the achievement condition versus the neutral condition.

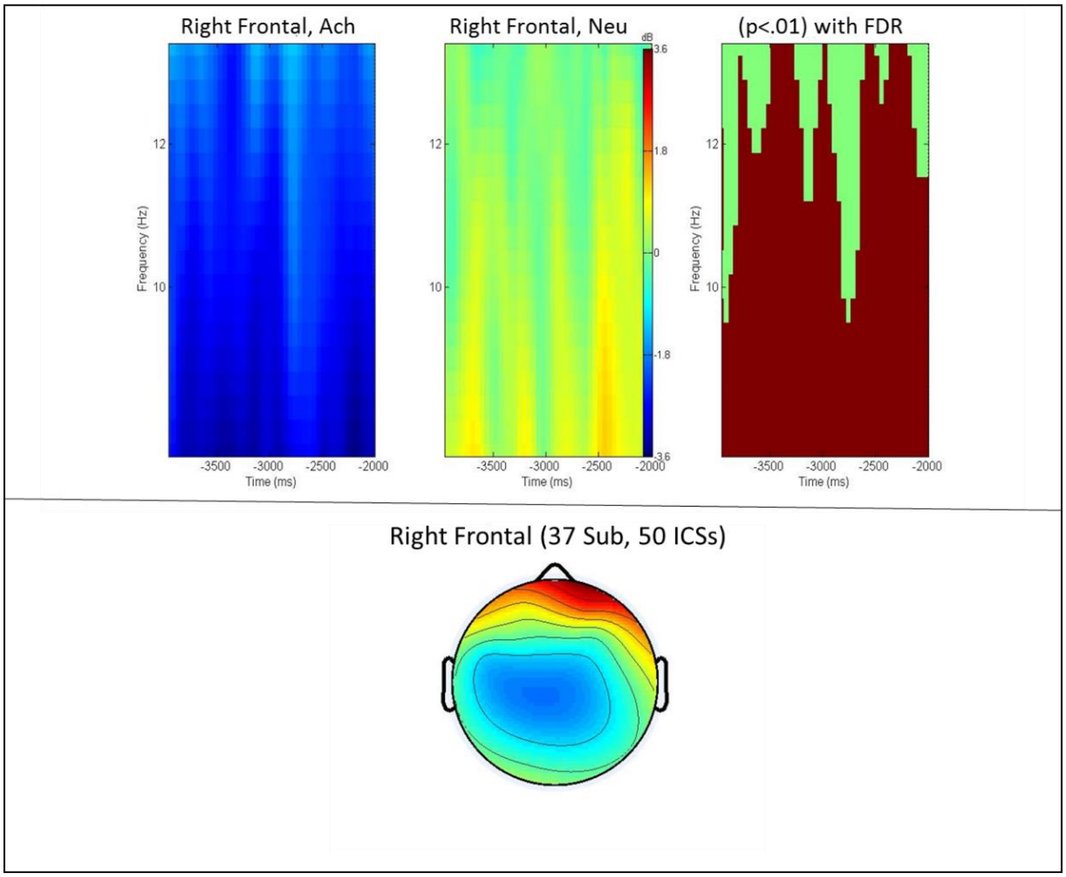

Figure 1.1 ERSP of Right Frontal cluster indicating significant alpha attenuation during ideation following the achievement prime

The second cluster's activation is distributed across the left frontal areas of cortex. 35 subjects produced 66 ICs in this cluster (See Figure 1.2). T-tests comparing the achievement prime and neutral prime are presented in Figure 1.2. Left frontal areas of cortex are responsible for speech production as well as emotion (Fuster 1988).

After exposure to the achievement prime, individuals showed significant alpha attenuation in the neutral condition (Panel 2) as compared to the achievement condition (Panel 1). Panel 3 shows areas where they significantly differed. Alpha band differences were detected between 4000ms and 2000ms before the subject entered ideas into the chat simulator. Furthermore, these changes were evident across the alpha frequency band (8-

13Hz), showing greater cortical attention after the a priori neutral prime in this region when compared to the a priori neutral prime. Since the neutral prime is designed to have no effect, this finding could indicate that the a priori achievement prime "shifts" cognitive resources from left frontal to right frontal regions of frontal cortex.

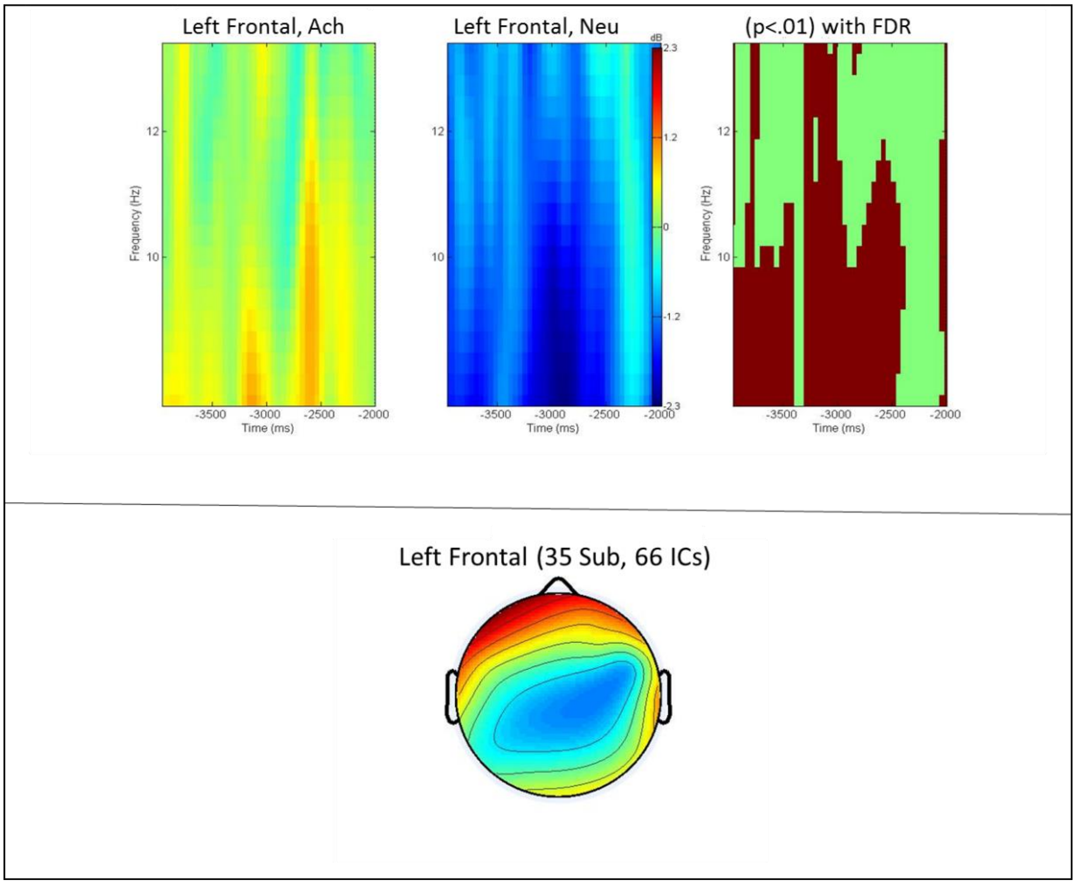

Figure 1.2 ERSP of Left Frontal cluster indicating significant alpha attenuation during ideation following the neutral prime

The third cluster is located posterior to the central sulcus in the right parietal region. 33 subjects produced 138 ICs in this cluster. This cluster is more geographically dispersed than the second cluster and shows parietal activation (See Figure 1.3). The parietal region of cortex is associated with integrating sensory information (Fogassi et al. 2005).

T-tests comparing the achievement prime and neutral prime are presented in Figure 1.3. The a priori priming treatment did not create significant differences in cognitive processing during ideation in the parietal region of the brain. In a priori priming, the sensory information that needs to be integrated during the chat is similar between the two treatments because the achievement and neutral priming was delivered before the chat session and during the EBS session the chat room interface was similar across the achievement and neutral conditions.

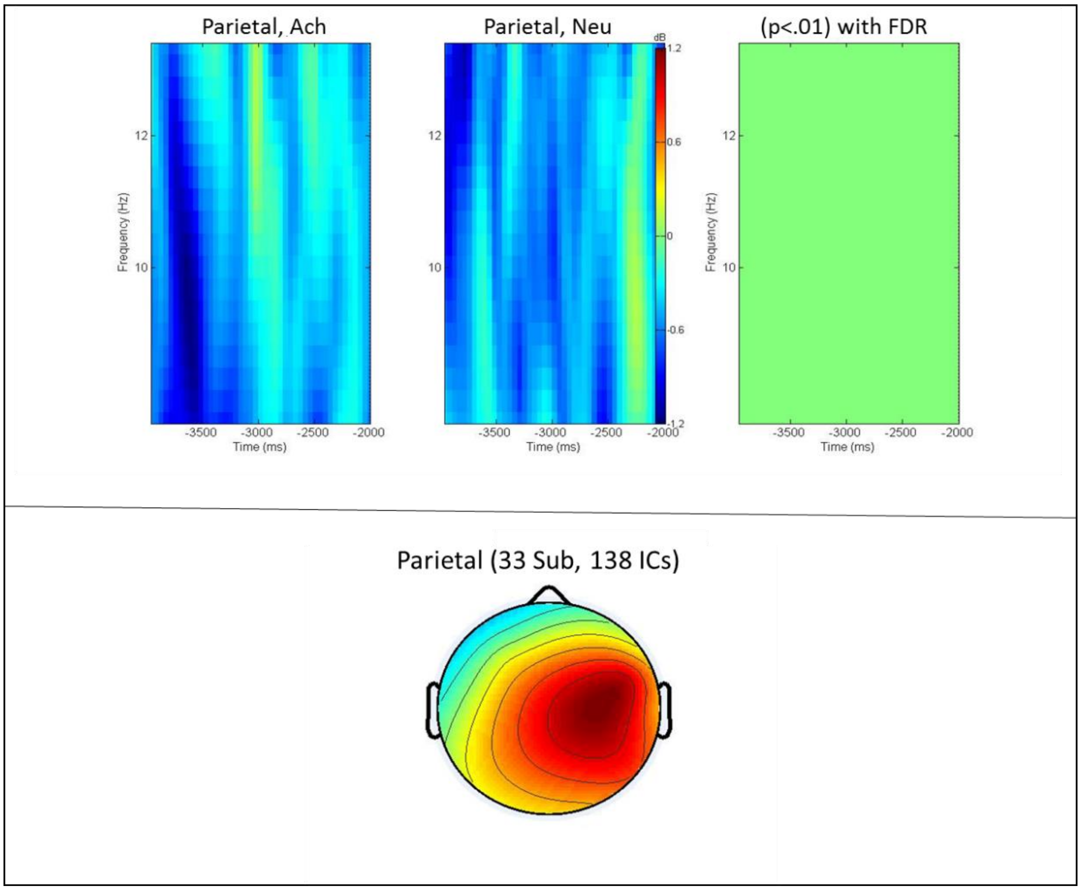

Figure 1.3 ERSP of Left Frontal cluster indicating significant alpha attenuation during ideation following the neutral prime

3.4.3.2. Cognitive changes over time

In examining the changes in cognition due to the achievement priming effect in an EBS session, it is important to examine the cognitive changes in ideation over time. To do this, the same clusters from the full analysis were used and ideas were coded into occurring in the first half of the EBS session or the last half of the EBS session. ERSPs were generated for each of the clusters for the first and last half of the EBS session.

The right frontal cluster time analysis showed that significant differences occurred across the alpha frequency spectrum between the achievement and neutral treatments during the first half of the EBS session. Significant alpha attenuation (i.e., increased cognition) was observed in the achievement condition as compared to the neutral condition during the first half of the EBS session. These changes did not persist during the second half of the EBS session, indicating the priming effect's changes in cognition began to wear off during the second half of the task. Therefore, Hypotheses 8a and 8b are partially supported, the priming effect's initial impact on cognition begins to diminish during the latter stages of the EBS task. The ERSP is shown in Figure 1.4

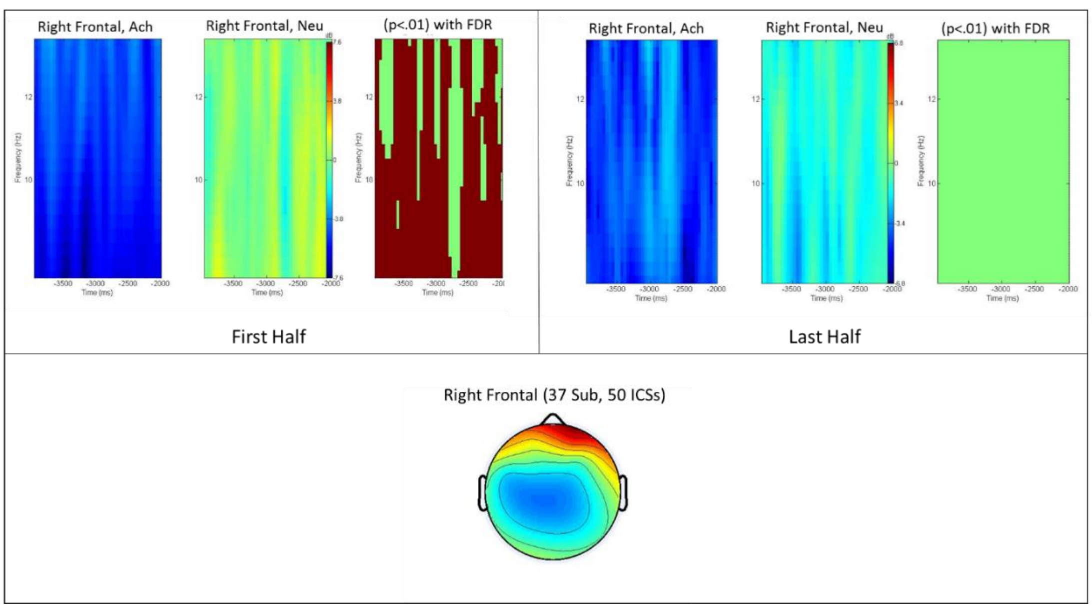

Figure 1.4 ERSP of Right Frontal cluster indicating significant alpha attenuation during ideation in the first half of the EBS session following the achievement prime. No significant differences in cognition were observed in the last half of the EBS session.

The left frontal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and neutral treatments during the first half of the EBS session. Furthermore, no significant differences were observed during the second half of the EBS session. The ERSP is shown in Figure 1.5.

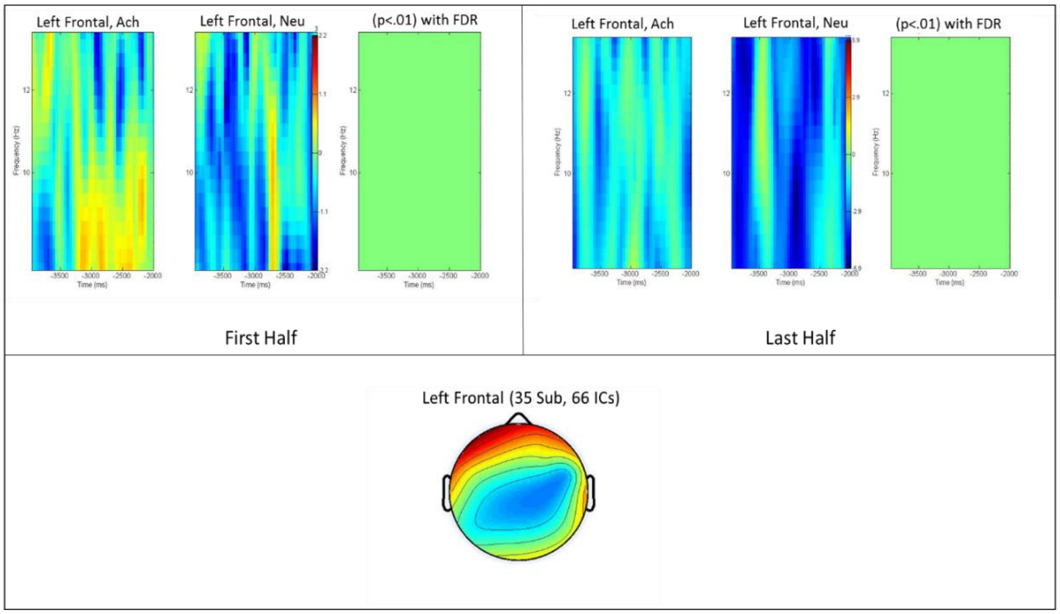

Figure 1.5 ERSP of Left Frontal cluster showing no significant differences in cognition during the first and last half of the EBS session.

The parietal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and neutral treatments during the first half of the EBS session. Furthermore, no significant differences were observed during the second half of the EBS session. The ERSP is shown in Figure 1.6.

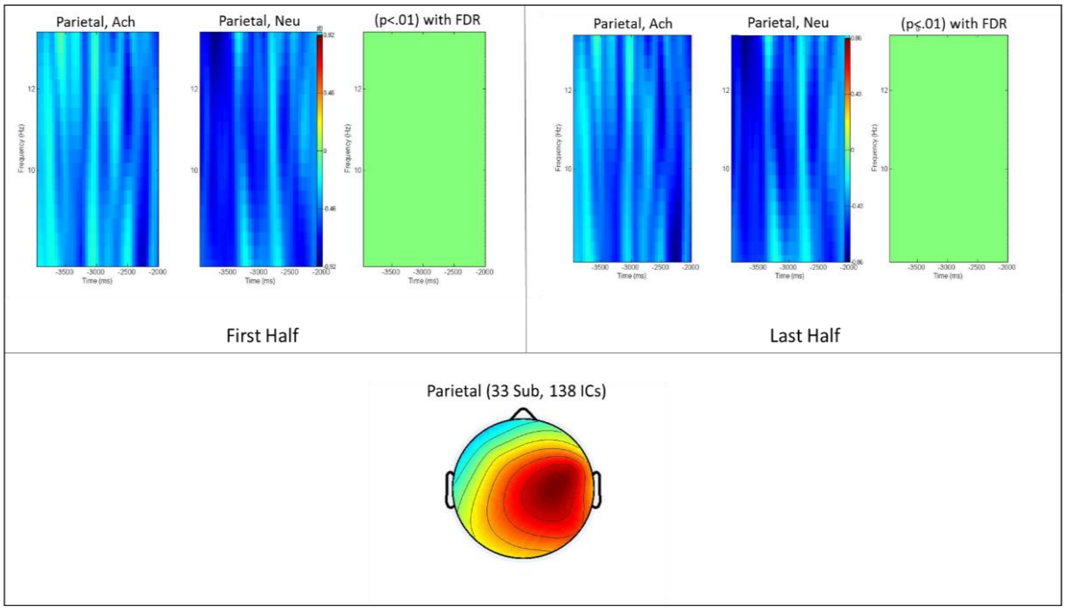

Figure 1.6 ERSP of Parietal cluster showing no significant differences in cognition during the first and last half of the EBS session.

These EEG results, taken together, indicate that the achievement prime significantly affects cognition in right frontal cortex, which is associated with creative and divergent thinking. The priming effect on right frontal cortex decays overtime and is no longer evident at $p = .01$ during the last half of the EBS session. The significant difference observed in left frontal cortex is not observed in the first and last half of the EBS session, likely due to a lack of statistical power from the decreased number of ideas. Finally, the third cluster shows no significant differences over the entire EBS session, nor at the first or last half of the EBS session.

3.4.4. *Changes in Emotion*

The psychophysiological measures utilized in this study were analyzed using hierarchical linear modeling (HLM). A two-level model was created with the psychophysiological measure at the first-level. A 20-second average of skin conductance and corrugator activation was taken, representing 10 seconds before the subject entered an idea and the 10 seconds after a subject entered an idea. The treatment and whether the

idea was in the first or second half of the chat session were included as indicators in the first-level HLM model. The second-level of the HLM was the subject.

For skin, a measure of arousal, the results do not indicate a main effect of achievement (b = -.044, p = .490). This indicates that the a priori prime resulted in no different arousal between achievement and neutral treatments during the EBS session. Similarly, corrugator activation, a measure of positive emotional valence, did not significantly differ between the a priori achievement and neutral priming condition (b = .043, p = .806). Therefore Hypotheses 5a and 5b are not supported. A table of means and beta coefficients is provided in Table 1.4.

Table 1.4 Means, standard deviations, and results of HLM statistical analyses for skin conductance and corrugator

		Achievement Prime		**Neutral Prime**		**B**	**p-value**
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**		
Skin Average	47	2.06	1.25	2.08	1.21	-0.044	0.490
Corrugator Average	47	1.05	1.38	1.06	1.4	0.043	0.806

3.4.4.1. Changes in emotion over time

In delineating whether the behavioral differences in idea fluency and creativity occur via an emotional or cognitive route, it is important to understand the changes observed in emotion over time after exposure to an achievement a priori prime. HLM was used to elucidate changes in emotion between achievement and neutral priming during the first half and the last half of the EBS session.

For skin conductance, the measure of arousal, a main effect of time was observed in comparing the first and last half of the EBS session. Arousal significantly decreased during the last half of the EBS session (b = -0.12, p = .029). However, the interaction of treatment and half was not significant (b = 0.01, p = .850), indicating the changes in arousal over time in the EBS session were not due to the treatments. This finding likely indicates that the subjects experienced fatigue towards the end of the EBS session following the a priori prime, regardless of treatment. Therefore, Hypotheses 6a and 6b are not supported.

For corrugator, the measure of positive valence, no significant differences were observed in the first or last half of the EBS session (b = -0.06, p = 0.315). Furthermore, there was no interaction observed between treatment and first and last half of the EBS session (b = 0.04, p = 0.585). Therefore, a priori priming did not create changes in emotion that persisted into the EBS session. Therefore, Hypotheses 7a and 6b are not supported. A table of means for the first and last half of the ideas generated in the EBS session is provided in Table 1.5.

Table 1.5 Means and standard deviations for skin conductance and corrugator in the first and last half of the EBS session

		Achievement Prime		Neutral Prime	
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**
Skin Average: First Half	47	2.14	1.30	2.11	1.21
Skin Average: Last Half	47	1.97	1.19	2.05	1.20
Corrugator Average: First Half	47	1.06	1.40	1.05	1.39
Corrugator Average: Last Half	47	1.05	1.35	1.08	1.42

Study One: A Priori Priming Discussion and Conclusion

This study examined the changes in behavior, cognition and emotion resulting from an a priori "achievement" prime. The overarching goals of this study were to examine whether priming lead to changes in cognition and/or emotion and whether those changes corresponded with behavioral results. The behavioral findings of this study, indicate that the a priori achievement prime makes individuals participating in a simulated team EBS session produce more ideas that are of better quality (i.e., the a priori achievement prime increases both idea fluency and creativity). An examination of the emotional and cognitive underpinnings of the behavioral change indicates that the behavioral changes correspond with specific cognitive changes, namely an increase in activation of right prefrontal cortex.

Previous studies have established that the right prefrontal cortex is associated with verbal creativity (Martindale 1999; Razoumnikova 2000). In one study, differences were observed in brain activation using Near Infrared Spectroscopy (NIRS) associated with divergent thinking tasks (Folley and Park 2005). The study used a task wherein subjects generated different uses for everyday objects. It found that increased right prefrontal activation was associated with increased ability to generate different uses for objects, thus indicating that right prefrontal activation was associated with generative creative thinking. The findings of study one, reflecting differences in right prefrontal cortex between the achievement and neutral conditions, indicate that following the a priori achievement prime, individuals utilize right prefrontal cortex more than after the neutral prime (as evidenced by alpha attenuation). This indicates that the achievement prime is activating a key creative center of the brain more than the neutral prime.

Similarly, there were differences observed in left prefrontal cortex, indicating that more cognition was being used to generate ideas following the neutral condition. Left prefrontal cortex contains language generation and working memory functional areas of the brain. Taken with the right prefrontal findings, these findings indicate that achievement priming “shifts” cognition to more creative regions of the brain during ideation (i.e., right prefrontal cortex).

One interpretation of these results is that utilizing the creative centers of the brain enable an individual to generate ideas more easily, thereby increasing the cognitive resources available to generate more ideas. The time course of the cognitive changes to right prefrontal cortex observed in this study was as expected. The a priori priming effect persisted throughout the first half of the EBS session but was no longer statistically different than the neutral prime in the latter half of the EBS session. However, the behavioral results indicate that despite cognition in right frontal decreasing in the last half, the individuals exposed to the achievement prime still generated more ideas than the individuals in the neutral prime. This finding indicates that the changes in behavior outlast the initial “boost” in cognition resulting from the a priori achievement prime.

The psychophysiological data in this study did not find any significant differences relating to ideation following achievement or neutral priming. This finding indicates that any emotional changes caused by a priori achievement priming are likely to be transient and do not persist into the following chat session.

The cognitive and emotion findings of study one together, indicate that the behavioral changes observed in subsequent EBS sessions result from changes in cognition induced by priming, not emotion (i.e., a priori priming results in behavioral changes by working through a cognitive route). This study cannot rule out that emotional changes occurred *during the priming session*, but it does show that no differences in emotion were observed *during ideation* in the EBS session. This finding provides evidence that the a priori achievement prime’s changes in ideation do not occur through the emotional route. Study two seeks to investigate if priming an individual concurrently, as they complete the task, will result in behavioral changes in idea fluency and creativity.

It also seeks to uncover if the same pattern of changes in cognition and emotion are observed as study one, specifically if the changes induced by achievement priming are a result of changes along the cognitive route.

STUDY TWO: CONCURRENT PRIMING

Introduction to concurrent priming

This study develops a new conceptualization of supraliminal priming, termed "concurrent" priming. Concurrent priming is the use of real-time priming, alongside a given task, to affect behavior on that task. Concurrent priming is expected to work in a similar manner to a priori priming, in that the concept being primed (e.g., achievement) will result in increased performance on the relevant task. The principle motivation in creating a concurrent prime it to address the limitations of a priori priming. This study tests two research questions. The first research question (RQ2a) examines whether concurrent priming produces the same behavioral changes as a priori priming in increasing idea fluency and creativity. The second research question examines whether the changes in behavior occur through a cognitive and/or emotional route. Thus, stated formally, the research questions are:

RQ2a: Does concurrent priming of achievement increase the fluency and quality of ideas produced during an EBS session?

RQ2b: In concurrent priming, does the prime affect idea generation performance through an emotional and/or cognitive route during an EBS session?

Theory and Hypotheses

A priori priming, by definition, is done by priming individuals prior to completing a task. Therefore, there is generally a priming session lasting several minutes before the individuals complete the task of interest. Since the prime is removed before the task starts, the priming effect elicited begins to decay as the task commences (DeCoster and Claypool 2004). As discussed in previous sections, priming effects dissipate at a decay rate determined by a number of factors such as duration of priming session and stimuli used (DeCoster and Claypool 2004). As a result, the efficacy of the prime is most pronounced at the beginning of a task and diminishes as time from the prime elapses. In tasks, such as EBS, a priori priming is limited in its effectiveness because the priming effect is most needed in latter stages of the task.

Therefore, the integration of a priori priming into an organizational setting may be limited due to the priming session requirement and decay effects. Priming techniques that deliver the prime *concurrently* within the brainstorming session may be more useful because the priming effect is being induced in real-time as the individual completes the task of interest. This study integrates a concurrent prime into the EBS software and examine effects on idea fluency and creativity.

In the concurrent prime, priming will occur with pictures instead of words since the scrambled sentence paradigm utilized in the first study would direct too much attention away from the brainstorming task. Pictures have been shown to be as effective as words in eliciting priming effects (Carr et al. 1982; Giner-Sorolla et al. 1999). Picture primes activate semantic networks in a similar way to priming with words by eliciting semantic interpretations of the pictures (Giner-Sorolla et al. 1999). For example, a picture of an individual crossing a finish line in first place creates a semantic interpretation along the lines of "that individual just won the race." This semantic interpretation activates mental representations related to achievement in the same manner as working directly with words related to achievement.

Another notable difference in the concurrent prime is that individuals will be using cognitive resources to complete a brainstorming task as well as to process the primes. It has been found that people do not need to consciously process the stimuli in order for a cognitive or emotional state to be invoked (Chartrand et al. 2006). There is much information present in our visual field constantly, and conscious processing does not occur for all the stimuli. However, primes presented in the visual field, readily apparent to an individual, have been shown to influence behavior even if the individual does not recall the content of the prime (Chartrand et al. 2006).

Since the concept being primed in concurrent priming is "achievement," the overall effect on idea fluency and creativity is expected to be similar to a priori priming. As a result, concurrent priming of the concept "achievement" is expected to increase idea fluency and creativity in a similar manner as a priori priming. Therefore, I hypothesize:

> *Hypothesis 1a: Concurrent priming of the concept "achievement" will increase idea fluency during an EBS session.*

> *Hypothesis 1b: Concurrent priming of the concept "achievement" will increase idea creativity during an EBS session.*

4.2.1. ***Concurrent priming and time***

While the overall effect of the concurrent prime is expected to be the same as a priori primes, it will likely follow a different time course. In a priori priming, the prime occurs before the task and behavior on the task is measured. The effect of the prime wears off as the task unfolds (Bargh and Chartrand 2000). One, relatively common assumption, in a priori priming is that the priming effect decays at the same rate across individuals. Therefore, the goal is to design a prime that will produce a priming effect that persists throughout the subsequent task. However, priming effects likely decay at different rates across individuals, which results in differential performance in the latter half of the task. This is to say, the relationship between the a priori priming effect and time during the subsequent task is inverse, as time on the task increases the priming effect decreases. One can also expect the confidence interval around the relationship to increase over time, representing varying rates of decay. These varying rates of decay result in unreliable priming effects at the end of the task.

Concurrent priming is designed to help this problem, in that priming is occurring *during* the task. The expected result is that, instead of an inverse relationship between priming effect and time, there will be a direct relationship. As time on the task unfolds, the priming effect is expected to build. Toward the beginning of the task/priming session, the priming effect will be relatively low. However, as the time on the task unfolds, the priming effect will increase to some individual maxima. Concurrent priming, therefore, is expected to be most beneficial in tasks where the priming effect is needed later on in the task, as opposed to right away.

EBS sessions are particularly suited to concurrent priming. In an EBS session, generally, there is a flood of ideas during the first minutes of the task, eventually settling into an ebb and flow of ideas in the latter stages of the task (Shepherd et al. 1995). In the latter stages of EBS sessions, the number of new ideas generated are few in comparison to the beginning of the task. Since priming has been shown to increase ideation fluency and creativity (Dennis et al. 2013; Postmes et al. 2001), it is probable that ideation in the latter parts of the task could be most susceptible to priming effects. Specifically, the beginning parts of EBS sessions, wherein many ideas are generated, could be nearing a ceiling effect where influences of priming simply cannot result in greater idea generation. However, towards the end of the task, the generation of more ideas is possible.

Concurrent priming is theorized to produce a priming effect that increases during the beginning of the task and is present in the latter stages of the task. As a result, the priming effect in concurrent priming, unlike a priori priming, is expected to offset ideation declines in the middle and late stages of the task. Therefore, EBS ideation performance could garner even a greater benefit with concurrent priming.

One consideration that must be taken into account with concurrent priming is the effect of being primed while working on a task. Since completing a task while being primed will place demands on cognitive resources, it is important to consider the effect of increased cognitive load on an individual's priming susceptibility. One meta-analysis on a priori priming found mixed results in the research literature. Increased cognitive load was found to increase susceptibility to primes, resulting in an increased overall priming effect (DeCoster and Claypool 2004). Under normal circumstances, people with sufficient cognitive resources will begin to exhibit an unconscious resistance to the primes, attenuating the overall priming effect (DeCoster and Claypool 2004). However, when cognitive load is high, people are slower to develop resistance away from the priming effect, resulting in greater susceptibility to the prime (DeCoster and Claypool 2004).

Therefore, it is expected that concurrent priming will influence idea generation in the latter stages of the task.

Hypothesis 2a: Concurrent priming of the concept of "achievement" will result in similar idea generation as neutral priming during the first half of an EBS session.

Hypothesis 2b: Concurrent priming of the concept of "achievement" will result in greater idea fluency than neutral priming during the last half of an EBS session.

Idea creativity has also been shown to be influenced by achievement priming (Dennis et al. 2013). It is expected that, during a concurrent EBS session, creativity will also increase as the time unfolds. During the beginning of the task, creativity will likely be similar in achievement and neutral priming conditions, whereas, in the latter parts of the task, priming is likely to become differentiated between the achievement and neutral priming conditions. Therefore, I hypothesize:

> *Hypothesis 3a: Concurrent priming of the concept of "achievement" will result in similar idea creativity as neutral priming during the first half of an EBS session.*

> *Hypothesis 3b: Concurrent* priming *of the concept of "achievement" will result in increased idea creativity than neutral priming during the last half of an EBS session.*

4.2.2. *Priming induced changes in psychophysiology*

Since concurrent priming, using pictures, is expected to activate the same semantic networks as a priori priming with words, the overall effect on cognition and emotion is expected to be similar. Changes in cognition, specifically attention, will occur after exposure to a concurrent, achievement prime. In this study, a concurrent prime is used. The prime is expected to have a similar effect on cognition measured as greater alpha attenuation in the frontal cortices after exposure to the achievement-oriented prime. Given the close relationship between frontal alpha-wave activity and attention, I hypothesize:

> *Hypothesis 4: Concurrent priming of the concept of achievement, as compared to a neutral prime, will increase attention during ideation in an EBS session.*

Repeated exposure to positive pictures, much like repeated exposure to positive words has shown to increase positive valence, while repeated exposure to negative pictures has been shown to increase negative valence (Bradley and Lang 1994; Kensinger and Schacter 2006). Therefore, I expect concurrent achievement priming to result in increased positive valence. Increased positive valence can be measured by the corrugator supercilli muscle becoming relatively more *deactivated* following exposure to the prime.

In addition, exposure to a concurrent achievement prime is expected to increase sympathetic nervous system activation (i.e., increased arousal), resulting in increased skin conductance in subsequent ideation during an EBS session. Therefore, the hypotheses for the effect of concurrent priming on emotional psychophysiological response are:

> *Hypothesis 5a: Concurrent priming of the concept of "achievement" will result in a physiological response that indicates more positive valence than neutral priming during ideation in an EBS session.*

> *Hypothesis 5b: Concurrent priming of the concept of "achievement" will result in a physiological response that indicates increased arousal than neutral priming during ideation in an EBS session.*

4.2.3. *Changes in cognition and emotion over time*

While the overall psychophysiological changes in cognition and emotion are expected to be similar to a priori priming, the time course over the EBS session is expected to be different. Specifically, the opposite pattern will be observed. The EBS session will begin with similar levels of attention, valence, and arousal between achievement and neutral priming. However, as the achievement prime begins to elicit the priming effect, cognitive and emotional psychophysiological response will diverge. Levels of attention observed in the achievement priming condition, as measured by alpha attenuation, are expected to be higher than in the neutral priming condition. Similarly, the levels of valence and arousal observed across the priming conditions will begin at similar levels but, in the latter stages of the EBS session, will diverge. Higher valence is expected in the achievement priming condition during the middle and last third of the task when compared to valence levels in the neutral priming condition. In addition, greater arousal is expected in the achievement priming condition during the middle and last third of the task when compared to valence levels in the neutral priming condition. Therefore, *Hypothesis 6a: Concurrent priming of the concept of "achievement" will result in no different valence than neutral priming during ideation in the first half of an EBS session.*

Hypothesis 6b: Concurrent priming of the concept of "achievement" will result in more positive valence than neutral priming during ideation in the last half of an EBS session.

Hypothesis 7a: Concurrent priming of the concept of "achievement" will result in no different arousal than neutral priming during ideation in the first half of an EBS session.

Hypothesis 7b: Concurrent priming of the concept of "achievement" will result in increased arousal than neutral priming during ideation in the last half of an EBS session.

Hypothesis 8a: Concurrent priming of the concept of "achievement" will result in similar attention, as measured by alpha attenuation in the frontal cortices, than neutral priming during ideation in the first half of an EBS session.

Hypothesis 8b: Concurrent priming of the concept of "achievement" will result in greater attention, as measured by alpha attenuation in the frontal cortices, than neutral priming during ideation in the last half of an EBS session.

Study Two: Concurrent Priming Methodology

4.3.1. *Participants*

Fifty-six students were recruited from the same introductory business course as study one. The course consisted of sophomores and juniors, and participants completed the study for extra credit. Demographic variables were obtained to provide average age and gender distribution. Age ranged from 18 to 25 with the average age being 20 years of age. Thirty-one participants (55.4%) were male and 25 participants were female (44.6%).

4.3.2. *Tasks*

The same EBS tasks were used in study two as in study one. There was one 15 minute task on generating ideas to reduce pollution and one 15 minute task on increasing tourism.

4.3.3. *Treatments*

The second study was a repeated measures experiment using concurrent priming with pictures. Each participant received two within subject treatments: achievement priming and neutral priming. Participants generated ideas using the simulator from study one, but with priming delivered by pictures presented in a banner on the right side of the screen. Participants in this treatment group generated ideas while they were being primed. The image in the right hand banner updated to a new image every 20 seconds, and there were 30 different pictures presented in each task. The pictures were presented in landscape format with a resolution of 400 x 300 pixels.

The achievement priming condition for concurrent priming consisted of a set of 30 images oriented towards the concept of "achievement," while the neutral priming condition consists of 30 images designed to have no effect. The images for the achievement and neutral priming conditions were rated by a group of students on achievement, arousal, and valence. Examples of the achievement and neutral images are provided in Appendix C of this document. The achievement-oriented images significantly differed from neutral images on achievement rating by students ($t(58) = 7.87$, $p < .001$) (for a full summary of results see Appendix A). Arousal was rated on a scale form 1 (low arousal) to 9 (high arousal), and valence is rated from 1 (negative) and 9 (positive). The neutral images were moderate in arousal (M = 4.64, S.D. = 0.39) and moderate in valence (M = 5.32, S.D. = 0.49). The achievement priming images had higher arousal (M = 5.14, S.D. = 0.41) and more positive valence (M = 5.47, S.D. = 0.61). The achievement priming images significantly differed from the neutral priming words on both arousal ($t(58) = 4.41$, $p < .001$) and valence ($t(58) = 3.75$, $p < .001$).

4.3.3.1. Dependent Variables

The dependent variables were the same as study one and consisted of both behavioral and physiological measures.

4.3.3.2. Behavioral Measures

The behavioral measures were the same as Study One. Idea fluency, measured as number of unique ideas generated, and creativity measures were collected. As in study one, the creativity measures included assessment of novelty, workability, and relevance to obtain a measure of overall creativity and total number of creative ideas.

4.3.3.3. Physiological Measures

The physiological measures were the same as study one and included EEG measures, as well as, psychophysiological measures and skin conductance.

4.3.4. *Control Variables*

The control variables were the same as in Study One.

4.3.5. *Procedure*

The procedure of study two was similar to study one. However, the prime was delivered concurrently with the EBS session. Participants completed the experimental procedure individually after providing informed consent approved by the university's Institutional Review Board. The experiment took place in an individual lab room at a research institute. The entire research session took approximately 60 minutes. The surveys presented in the experiment were controlled by MediaLab software (Jarvis 2010). The simulator software was developed using a Unity gaming shell.

Similarly to study one, participants were seated in a high back chair to minimize movement. They used a standard keyboard and mouse. The protocol began with a 10-minute series of personality questionnaires. The experimenter then explained the procedure for attaching the physiological electrodes and fitting the EEG apparatus, answering any questions posed by the participant. After obtaining adequate impedance readings for the EMG and EEG measures, the protocol continued with another brief handedness questionnaire.

The participants were randomly assigned to either the neutral or achievement priming condition. In addition, task order was counterbalanced with 31 participants receiving the pollution task first and 30 receiving the tourism task first. Participants then worked on the first EBS task for fifteen minutes. Next they completed a short survey to serve as a "distractor" between treatments. Participants repeated these same steps (priming game, idea generation) for the second priming manipulation and task. The participants were debriefed and the session concluded.

In total, the EEG apparatus was on the participants for approximately 45 minutes, during which the electrodes remained damp with the saline solution. Markers were inserted into the data by the simulation software, indicating when an idea had been entered into the chat room. This allowed for synchronization between the EBS session, EEG and EMG systems. When the discussion simulation was completed, the experimenter removed all physiological data collection sensors. Participants then completed the post-experiment questionnaire. Finally, they were be debriefed, told of the deception, asked not to inform others of the deception, and thanked for their time.

4.3.6. *Manipulation Checks*

Again for study two, it was essential to ensure that participants perceived the simulator as a real team discussion. All participants completed post-session questionnaires that asked if they have noticed anything unusual about the team discussion. A variety of distractor questions (e.g., satisfaction with discussion, perceived effectiveness) were also included to better ensure that manipulation check question did not stand out. Participants that recognized they were not interacting with real people were be removed from the study as failing the manipulation check. Eight of the 56 participants recognized they were not interacting with a simulator and were removed from the analysis, leaving 48 participants in the study. This represents a 14.3% of individuals failing the manipulation check, which is in line with prior studies ranging to 10-15% of the subjects failing manipulation checks (Garfield et al. 2001; Heninger et al. 2006).

Study Two: Concurrent priming results

4.4.1. *Behavioral results*

The statistical analyses for the behavioral component of study one were completed in SPSS PASW Statistics 18.0. A repeated-measures GLM was used to examine differences between the achievement and neutral priming conditions.

4.4.1.1. Idea fluency

Individuals produced significantly more ideas during the concurrent priming condition with achievement priming pictures than with neutral priming pictures ($F(1,45) = 9.58$, $p = .003$). The effect size was small with a Cohen's *d* of 0.27. The order in which the group received priming treatments did not affect the number of unique ideas generated ($F(1,45) = 0.78$, $p = .383$), nor did the task order for the pollution and tourism task ($F(1,45) = 0.25$, $p = .618$). Therefore, Hypothesis 1a was supported, the concurrent achievement prime led to significantly more ideas than the concurrent neutral prime.

4.4.1.2. Idea Creativity

Individuals produced a greater number of novel ideas following the concurrent achievement priming treatment than the neutral ($F(1,45) = 5.75$, $p = .021$). The effect size was medium with Cohen's *d* = .413. The order in which the participant receive d the priming conditions did not affect the number of novel ideas produced ($F(1,45) = 1.98$, p =

.167), nor did the order in which he or she received the pollution or tourism task (F(1,45) = 0.34, p = .564).

Individuals produced a greater number of workable ideas following the concurrent achievement prime than the neutral prime (F(1,45) = 13.97, p = .001). The effect size was medium with a Cohen's *d* = .423. The order in which the participant received the priming conditions did not affect the number of workable ideas produced (F(1,45) = 1.12, p = .295), nor did task order (F(1,45) = 0.09, p = .763).

Individuals produced a greater number of relevant ideas following the concurrent achievement prime than the neutral prime (F(1,45) = 12.52, p = .001). The effect size was small with Cohen's *d* = .366 . The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,45) = 0.018, p = .893), nor did task order (F(1,45) = 1.307, p = .259).

The findings on novelty, workability, and relevance, taken together, provide full support for Hypothesis 1b. The concurrent achievement prime significantly increases the creativity of ideas produced in during an EBS session.3.

Table 2.1 Means, standard deviations, and results of statistical analyses

Measures	n	Achievement Prime		Neutral Prime		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	48	13.81	6.34	12.27	4.93	9.58	0.003
Number of Novel Ideas	48	3.88	3.19	2.75	2.16	5.75	0.021
Number of Workable Ideas	48	12.56	6.01	10.71	4.23	13.97	0.001
Number of Relevant Ideas	48	10.81	4.95	9.19	3.84	12.52	0.001

4.4.2. *Concurrent priming and time: Behavioral Analysis*

4.4.2.1. Idea fluency and time

Individuals produced significantly more ideas in the achievement treatment compared to the neutral treatment during the first half of the EBS session ($F(1,45) = 81.68$, $p < .001$). The effect size was small with a Cohen's *d* = .31. The order in which the participant received the priming conditions did not affect the number of ideas produced in the first half of the EBS session ($F(1,45) = .133$, $p = .717$), nor did task order ($F(1,45) = .358$, $p = .553$). These findings support the alternate to Hypothesis 2a, the concurrent achievement priming effect appears to have an influence on idea fluency during the first half of the brainstorming session. The means, standard deviations, and results are provided in Table 1.2.

In addition, individuals produced significantly more ideas in the achievement treatment compared to the neutral treatment during the last half of the EBS session ($F(1,45) = 9.58$, $p = .003$). The effect size was small with a Cohen's *d* = .17. The order in which the participant received the priming conditions did not affect the number of ideas produced in the last half of the EBS session ($F(1,45) = .775$, $p = .383$), nor did the task order ($F(1,45) = .253$, $p = .618$). Therefore, Hypothesis 2b was supported, the priming effect generated by the concurrent achievement prime impacts the last half of the EBS session when compared to the neutral prime. The means, standard deviations, and results are provided in Table 1.3.

In addition to the tests of the hypotheses, I also compared the first half of concurrent achievement idea fluency against the last half of achievement with a post-hoc pairwise comparison. The number of ideas generated in the first half of an EBS session after the achievement prime was significantly higher than the last half of ideas generated in an EBS session after the achievement treatment ($t(94) = 4.52$, $p < .001$). In addition, the number of ideas produced during the first half of the EBS session in the neutral treatment significantly differed from the number of ideas produced in the last half of the EBS session of the neutral treatment ($t(94) = 4.47$, $p < .001$). This indicates that the concurrent achievement prime produces a priming effect that has more of an influence on the first half of the EBS session. However, the achievement treatment still significantly differed from the neutral treatment in the last half of the EBS session.

4.4.2.2. Idea creativity and time

Individuals produced a greater number of novel ideas following the concurrent achievement priming treatment during the first half of an EBS session when compared to neutral ($F(1,45) = 64.16$, $p < .001$). The effect size was medium with Cohen's $d = .442$. The order in which the participant received the priming conditions did not affect the number of novel ideas produced ($F(1,45) = 1.46$, .233), nor did the order in which he or she received the pollution or tourism task ($F(1,45) = .05$, $p = .823$).

Individuals produced a greater number of workable ideas following the concurrent achievement prime during the first half of an EBS session when compared to neutral ($F(1,45) = 226.08$, $p < .001$). The effect size was medium with a Cohen's $d = .429$. The order in which the participant received the priming conditions did not affect the number of workable ideas produced ($F(1,45) = 1.04$, $p = .313$), nor did task order ($F(1,45) = 0.20$, $p = .661$).

Individuals produced a greater number of relevant ideas following the concurrent achievement prime during the first half of an EBS session when compared to neutral ($F(1,45) = 215.20$, $p < .001$). The effect size was medium with Cohen's $d = .433$. The order in which the participant received the priming conditions did not affect the number of relevant ideas produced ($F(1,45) = .19$, $p = 661$), nor did task order ($F(1,45) = .18$, $p =$

.671). These findings support the alternate to Hypothesis 3a, indicating the concurrent prime has an impact during the early stages of the task. The means, standard deviations, and results are provided in Table 1.2.

Similarly, individuals produced a greater number of novel ideas following the concurrent achievement priming treatment during the last half of an EBS session when compared to neutral ($F(1,45) = 5.75$, $p = .021$). The effect size was small with Cohen's *d* = .297. The order in which the participant received the priming conditions did not affect the number of novel ideas produced ($F(1,45) = 1.98$, $p = .167$), nor did the order in which he or she received the pollution or tourism task ($F(1,45) = 0.338$, $p = .564$).

Individuals produced a greater number of workable ideas following the concurrent achievement prime during the last half of an EBS session when compared to neutral ($F(1,45) = 13.974$, $p = .001$). The effect size was small with a Cohen's *d* = .237. The order in which the participant received the priming conditions did not affect the number of workable ideas produced ($F(1,45) = 1.122$, $p = .295$), nor did task order ($F(1,45) = .09$, $p = .763$).

Individuals produced a greater number of relevant ideas following the concurrent achievement prime during the last half of an EBS session when compared to neutral ($F(1,45) = 12.52$, $p = .001$). The effect size was small with Cohen's *d* = .256. The order in which the participant received the priming conditions did not affect the number of relevant ideas produced ($F(1,45) = .02$, $p = .893$), nor did task order ($F(1,45) = 1.31$, $p = .259$). These findings support Hypothesis 3b and indicate that the achievement priming effects both the first and latter stages of the EBS task. The means, standard deviations, and results are provided in Table 1.3.

Table 2.2 Means, standard deviations, and results of priming time statistical analyses for first half of the EBS session

Measures	N	Achievement Prime First Half		Neutral Prime First Half		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	48	8.52	4.08	7.42	3.10	81.68	< 0.001
Number of Novel Ideas	48	2.43	2.05	1.66	1.36	64.16	< 0.001
Number of Workable Ideas	48	7.79	3.74	6.42	2.53	226.08	< 0.001
Number of Relevant Ideas	48	6.69	3.10	5.50	2.34	215.20	< 0.001

Table 2.3 Means, standard deviations, and results of priming time statistical analyses for last half of the EBS session

Measures	n	Achievement Prime Last Half		Neutral Prime Last Half		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	48	5.29	2.81	4.85	2.50	9.579	0.003
Number of Novel Ideas	48	1.45	1.41	1.09	0.97	5.75	0.021
Number of Workable Ideas	48	4.77	2.29	4.29	1.73	13.97	0.001
Number of Relevant Ideas	48	4.13	1.89	3.69	1.53	12.52	0.001

4.4.3. *Changes in Cognition*

4.4.3.1. Event-related Spectral Perturbation (ERSP) analysis

Similarly to study one, the *K*-means cluster analysis produced three neurological clusters of interest. These were selected initially according to the number of subjects and ICs represented in each cluster and were supported by visual inspection of the corresponding scalp maps. Scalp maps provide information as to the dispersion of activity within a frequency band across the scalp. Due to the idiosyncratic nature of neural activity within each participant, some individuals did not produce independent components in each cluster. One cluster, for example, contained data from 32 subjects, meaning 16 of the 48 usable EEG subjects did not produce neural responses statistically related to the others in the regions identified by the cluster. This may be explained by differences in brain lateralization and structure among participants in the study. Another possibility is the signal-to-noise ratio in the EEG signal is smaller than other types of bioelectrical activity. Participants which produced many muscular artifacts may have produced ICs that were predominated by the much larger variance created by these muscle movement (and not neural activity).

The first cluster is geographically distributed across the right frontal areas of cortex with a strong activation apparent in this region. This cluster contained data from 32 subjects and 99 ICs. This cluster appears to be highly localized to the right frontal lobe with some dispersion to left frontal cortex as well (See Figure 2.1). This cluster is similar to the right frontal cluster observed in study one. The study one cluster seems to be located more medially than this one in study two. Likewise, this cluster is less concentrated that the similar cluster in Study 1. The right frontal activation could be indicative of increased creativity on the task, which has been shown in prior studies to be a region of the brain responsible for creativity and divergent thinking (Carlsson et al. 2000; Razoumnikova 2000).

T-tests of the achievement prime and neutral prime are presented in Figure 2.1, Individuals showed significant alpha attenuation (i.e., increased cognition) (Panel 1) in the achievement prime as compared to the neutral condition (Panel 2). Panel 3 shows areas where they significantly differed. Alpha band differences were detected between 4000ms and 2500ms before the subject entered ideas into the chat simulator. Furthermore, these changes were evident across the alpha frequency band (8-13Hz), showing greater cortical attention after the a priori achievement prime in this region when compared to the a priori neutral prime. This is indicative of the subjects using more cognitive resources in the creative regions of the brain during the achievement priming condition when compared to the neutral priming condition.

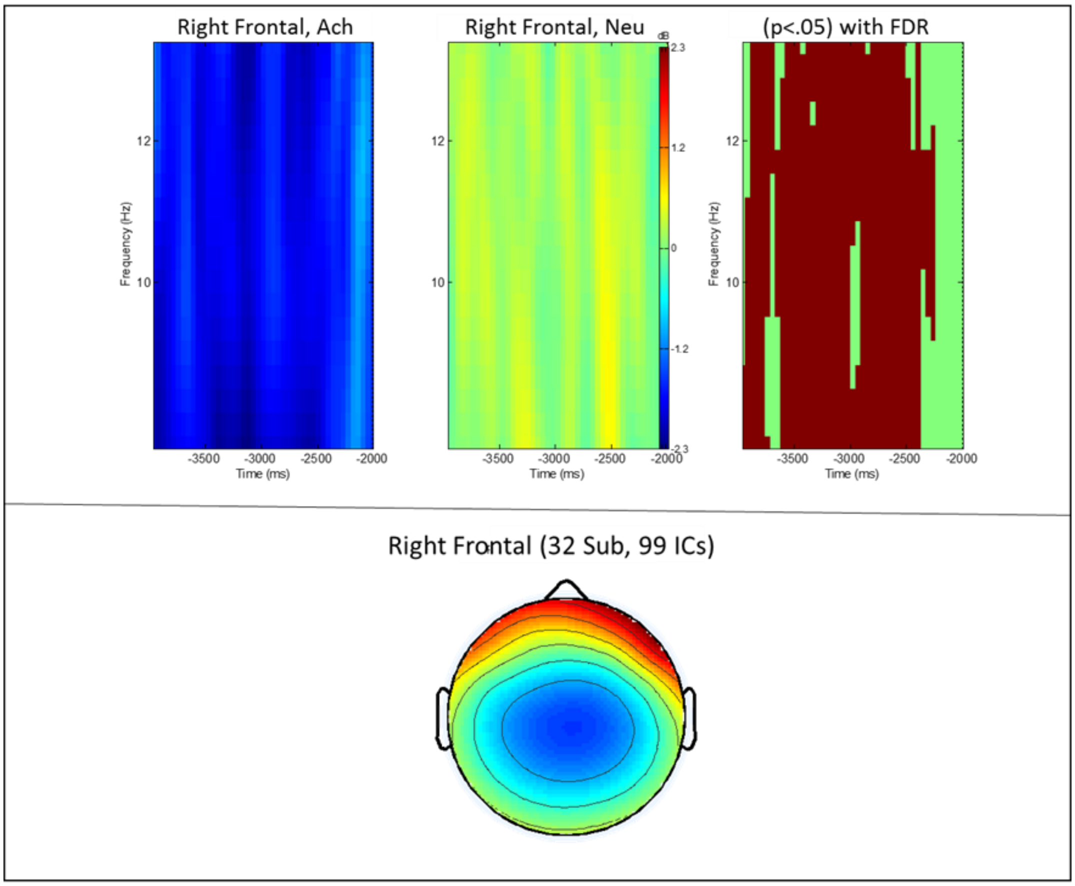

Figure 2.1 ERSP of Right Frontal cluster indicating significant alpha attenuation during ideation following the concurrent achievement prime

The second cluster is similar to the left frontal cluster observed in study one. This cluster is distributed across the left frontal areas of cortex with a strong activation apparent in this region near Broca's Area (the language generation region of the brain). The cluster in study two is slightly more lateral and concentrated near Broca's than the cluster observed in study one. This cluster contained data from 31 subjects and 128 ICs. This cluster appears to be highly localized to the left frontal lobe than the analogous cluster from study one (See Figure 2.2). This region is heavily involved in cognitive load and language production.

T-tests of the achievement prime and neutral prime are presented in Figure 2.2. After exposure to the achievement prime, individuals showed no different alpha attenuation during the achievement condition (Panel 1) as compared to the neutral condition (Panel 2). Panel 3 shows no areas where they significantly differed. This finding indicates that the achievement-oriented prime did not significantly change cognition in the language production areas of the brain as it did in the a priori prime in study one.

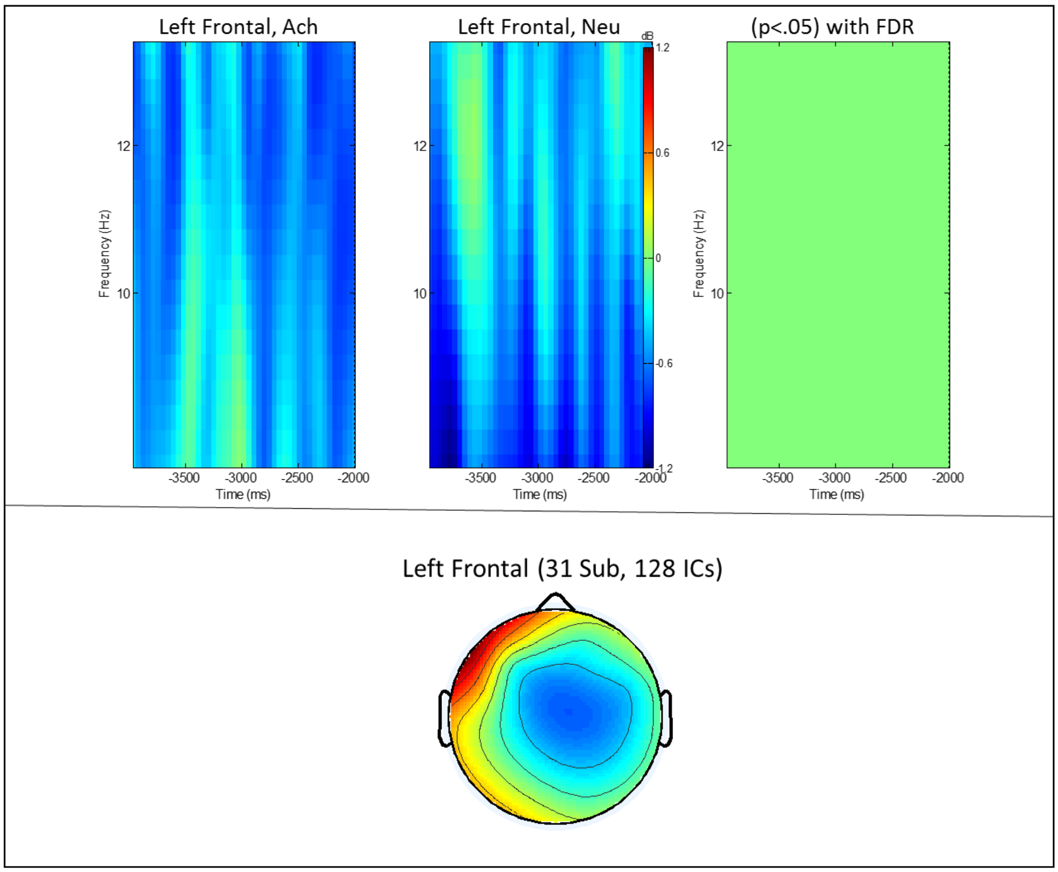

Figure 2.2 ERSP of Left Frontal cluster indicating significant alpha attenuation during ideation following the concurrent achievement prime

The third cluster is similar to the parietal cluster observed in study one. It is localized to an area posterior to the central sulcus in the parietal lobe. During the concurrent prime, the participants were exposed to images as well as the chat room.

These images differed between treatments. The parietal lobe is responsible for integrating sensory information and relaying it to frontal regions for further processing. This cluster contained data from 31 subjects and 204 ICs (See Figure 2.3).

T-tests of the achievement prime and neutral prime are presented in Figure 2.3. After exposure to the achievement prime, individuals showed significantly different alpha attenuation during the achievement condition (Panel 1) as compared to the neutral condition (Panel 2). Panel 3 shows no areas where they significantly differed. Subjects showed significantly different alpha attenuation (i.e., increased attention in the achievement condition) from -4000 ms to -2500 ms across the alpha frequency band. These findings could indicate that the individuals were processing the achievement related pictures, embedded in the chat session during the task, differently from the neutral images.

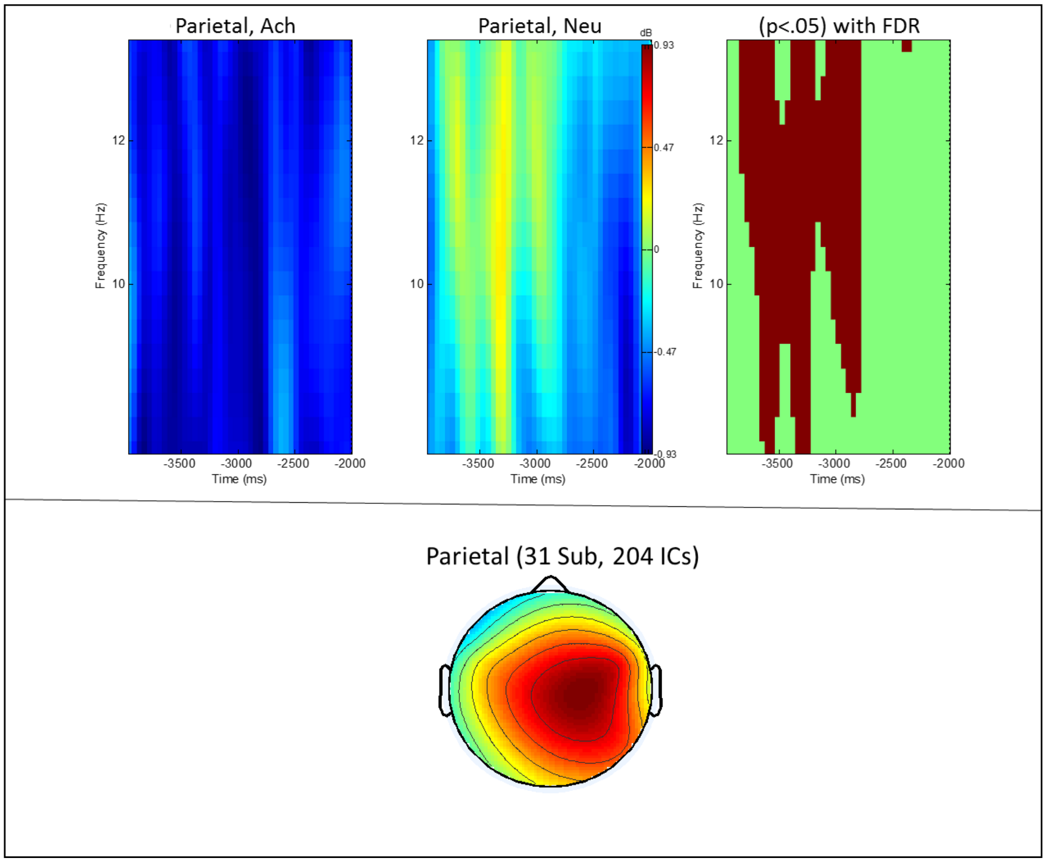

Figure 2.3 ERSP of Parietal cluster indicating significant alpha attenuation during ideation following the concurrent achievement prime

4.4.3.2. Cognitive changes over time

In examining the changes in cognition due to the concurrent achievement priming effect in an EBS session, it is important to examine the cognitive changes in ideation over time. To do this, the same clusters from the full analysis were used and ideas were coded into occurring in the first half of the EBS session or the last half of the EBS session. ERSPs were generated for each of the clusters for the first and last half of the EBS session.

The right frontal cluster time analysis showed that no significant differences were observed between achievement and neutral priming during the first half of the EBS session. Some significant alpha attenuation (i.e., increased cognition) was observed in the achievement condition as compared to the neutral condition during the last half of the EBS session. However, differences in cognition were only observed around the middle and lower alpha frequency band from -3000 to -2500ms. While the images do look different in the last half, there likely was not enough statistical power to uncover the differences, due to the lower amount of ideas in the second half. Therefore, Hypotheses 8a and 8b are partially supported, the priming effect's impact on cognition is apparent during the latter stages of the EBS task. The ERSPs are shown in Figure 2.4

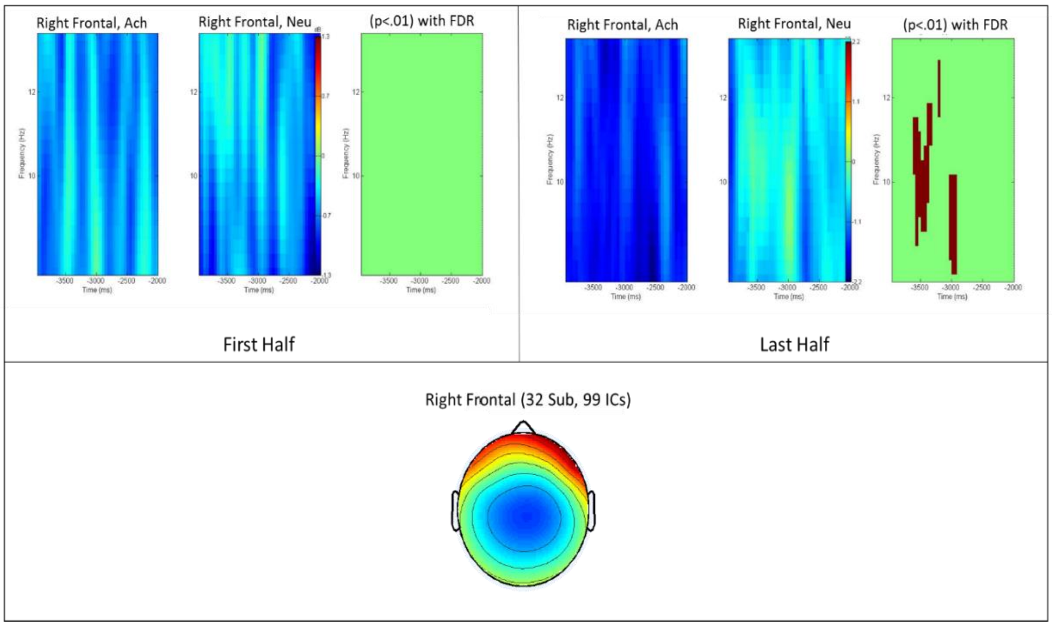

Figure 2.4 ERSP of Right Frontal cluster indicating significant alpha attenuation during ideation in the last half of the EBS session during the achievement prime. No significant differences in cognition were observed in the first half of the EBS session.

The left frontal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and neutral treatments during the first half of the EBS session. Furthermore, no significant differences were observed during the second half of the EBS session. The ERSPs are shown in Figure 2.5. This finding indicates that in the speech production region of the brain, there was no significantly different cognition during ideation in either the first or last half of the EBS session.

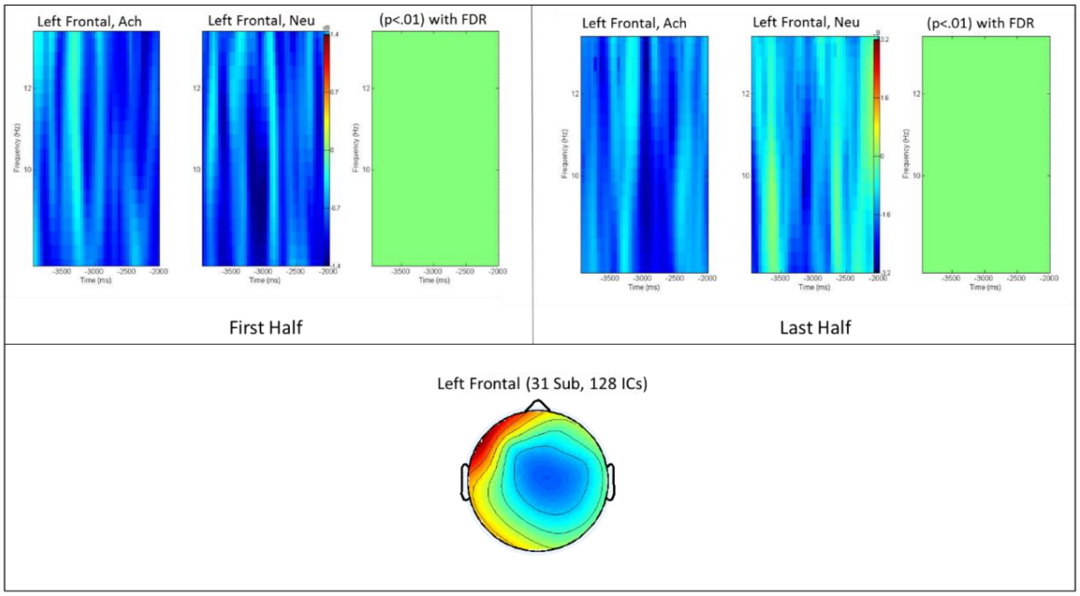

Figure 2.5 ERSP of Left Frontal cluster showing no significant differences in cognition during the first and last half of the EBS session.

The parietal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and neutral treatments during the first half of the EBS session. Furthermore, no significant differences were observed during the second half of the EBS session. The ERSPs are shown in Figure 2.6.

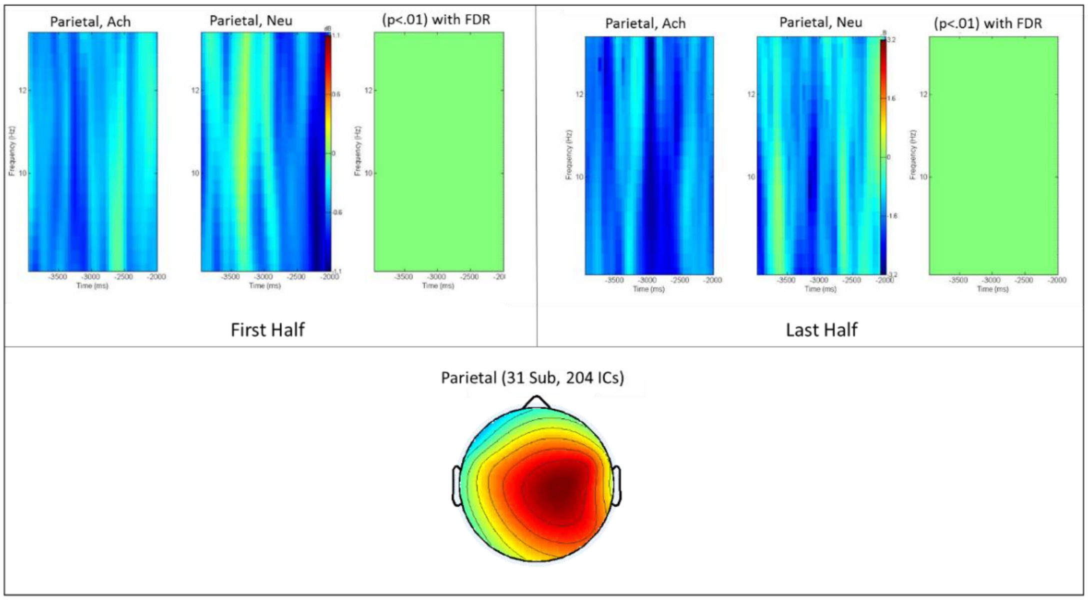

Figure 2.6 ERSP of Parietal cluster showing no significant differences in cognition during the first and last half of the EBS session.

These EEG results, taken together, indicate that the concurrent achievement prime significantly affects cognition in right frontal cortex, much like study one. This region is often associated with creative and divergent thinking. The cognitive changes of the priming effect are evident in right frontal during the last half of the EBS session. There were no significant differences observed in left frontal (i.e., Broca's area, language production). Finally, the third cluster shows significant differences over the entire EBS session, but not when taken at the first or last half of the EBS session, likely due to a lack of statistical power after the ideas were split.

4.4.4. *Changes in Emotion*

The psychophysiological measures utilized in this study were analyzed using hierarchical linear modeling (HLM). A two-level model was created with the psychophysiological measure at the first-level. A 20-second average of skin conductance and corrugator activation was taken, representing 10 seconds before the subject entered an idea and the 10 seconds after a subject entered an idea. The treatment and whether the

idea was in the first or second half of the chat session was included as indicators in the HLM model. The second-level of the HLM included an indicator representing the subject number.

For skin, a measure of arousal, the results do not indicate a main effect of achievement (b = .011, p = .805). This indicates that the concurrent prime resulted in no different arousal between achievement and neutral treatments during the EBS session. Similarly, corrugator activation, a measure of positive emotional valence, did not significantly differ between the concurrent achievement and neutral priming condition (b = -.081, p = .361). Therefore Hypotheses 5a and 5b are not supported. A table of means and beta coefficients is provided in Table 2.4.

Table 2.4 Means, standard deviations, and results of HLM statistical analyses for skin conductance and corrugator

		Achievement Prime		Neutral Prime		B	p-value
Measures	**N**	**Mean**	**Std.**	**Mean**	**Std.**		
Skin Average	45	1.05	0.96	1.92	0.99	0.011	0.805
Corrugator Average	45	1.60	1.76	1.71	1.80	-0.081	0.361

4.4.4.1. Emotional changes over time

In delineating whether the behavioral differences in idea fluency and creativity occur via an emotional or cognitive route for the concurrent prime, it is important to understand the changes observed in emotion over time after exposure to an achievement concurrent prime. HLM was used to observe these changes in emotion between achievement and neutral priming during ideation in the first half and the last half of the EBS session.

For skin conductance, the measure of arousal, no main effect of time was observed (b = -0.17, p = .689). Furthermore, the interaction of treatment and half was not significant (b = 0.02, p = .634). Therefore, Hypotheses 6a and 6b are not supported. For corrugator, the measure of positive valence, no significant differences were observed in the first or last half of the EBS session (b = -0.09, p = 0.088). Furthermore, there was no interaction observed between treatment and first and last half of the EBS session (b = 0.02, p = 0.811). Therefore, concurrent priming did not create changes in emotional state of the subjects in either arousal or valence during ideation in the EBS session. Therefore, Hypotheses 7a and 7b are not supported. A table of means for the first and last half of the ideas generated in the EBS session is provided in Table 2.5.

Table 2.5 Means and standard deviations for skin conductance and corrugator in the first and last half of the EBS session

		Achievement Prime		**Neutral Prime**	
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**
Skin Average: First Half	45	1.90	0.95	1.91	0.96
Skin Average: Last Half	45	1.81	0.97	1.92	1.03
Corrugator Average: First Half	45	1.68	1.80	1.76	1.83
Corrugator Average: Last Half	45	1.47	1.70	1.66	1.77

Study Two: Concurrent Priming Discussion and Conclusion

This study examined the changes in behavior, cognition and emotion resulting from a concurrent “achievement” prime integrated into the EBS tool. There were two primary goals to this study. The first was to examine whether the concurrent prime led to behavioral differences in idea fluency and creativity. The second was to investigate if the changes in behavior were a result of cognitive or emotional changes induced by the achievement prime.

The behavioral findings of this study, indicate that the concurrent achievement prime makes individuals participating in a simulated team EBS session produce more ideas that are of better quality (i.e., the concurrent achievement prime increases idea fluency and creativity). An examination of the emotional and cognitive underpinnings of the behavioral differences indicates that these changes, much like study one, correspond with specific cognitive changes, specifically an increase in activation of right prefrontal cortex.

These findings are similar to the findings in study one and indicate an increased use of areas of the brain associated with creativity when individuals are being exposed concurrently to an achievement prime. The differences in left frontal cortex that were observed in a priori priming in study one were not observed when the individuals were being primed concurrently in study two, indicating similar activation of the regions associated with working memory and language production between the concurrent treatments in study two.

Analysis of the time course of the priming effect generated by the concurrent prime indicates that the prime resulted in significant differences in cognition in right frontal during the last half of the EBS session. The differences were not observed in right frontal cortex during the first half of the EBS session. This conforms to the hypotheses that the priming effect takes time to impact cognition. Behaviorally, the individuals generated more ideas during the first and last half of the EBS session during the achievement prime when compared to the neutral prime.

The psychophysiological results indicate that there are no changes in emotion during ideation when being exposed to the achievement prime. Individuals had similar arousal and valence levels regardless of being exposed to the achievement or neutral images. This again supports the findings in study one, changes in idea fluency and creativity correspond to changes in cognition, not emotion.

This study provides significant value for management and the design of EBS systems, in that it indicates that it is possible to impact idea generation in an EBS session *without* needing to have an artificial 5-10 minute “priming” session beforehand. Study three delves deeper into the content of the images, specifically whether generic positive images create the same priming effect as images that are related to achievement. In addition, it seeks to elucidate whether these changes are tied to cognitive changes, emotional changes, or both.

STUDY THREE: ACHIEVEMENT VERSUS POSITIVE PRIMING

Introduction

The third study of this dissertation examines further whether the changes in ideation in electronic brainstorming are a result of the pictures being closely related to achievement *or* because achievement pictures are positive in both arousal and emotional valence (i.e., the pictures tend to be positive and happy pictures). As in study two, I use a concurrent prime to address research question three (RQ3). This study will delineate whether the achievement pictures significantly differ from other non-achievement, pictures that are also rated as high in arousal and positive valence. Thus, stated formally, the research questions for this study is:

RQ3: In concurrent priming, do the changes in ideation occur from the achievement-oriented nature of the images or the positive valence and arousal of the images?

Theory and hypotheses

Previous a priori priming literature has found that priming the concept of achievement activates an automatic goal to succeed, which in turn leads to better performance on tasks (Bargh et al. 2001). However, this study did not examine the arousal and valence of the words in the positive and neutral priming conditions.

Therefore, it is possible that the effect of the prime was related to the strong correlation between achievement-oriented words and the tendency for those words to be rated as high in both arousal and positive valence when compared to neutral words. The argument put forth by Bargh et al, is that achievement-oriented words activate semantic networks within the brain that correspond to succeeding, thus increasing the motivation for individuals to achieve (Bargh et al. 2001).

This dissertation seeks to establish whether the achievement prime works through a cognitive or emotional route, or potentially both. If the achievement-oriented prime *only* activates an individual's semantic network related to achievement, then one would expect an increase in fluency and creativity of ideas that occurs through priming the concept of achievement. However, if emotional changes occur in addition to activation of the semantic networks during achievement priming, then one would expect images that were high in arousal and positive valence to increase the fluency and creativity of ideas as well (i.e., cognitive and emotional changes induce similar ideation). In this scenario, the differences observed in concurrent priming of achievement and other pictures rated high in arousal and positive valence would produce similar idea fluency and creativity. Therefore, I hypothesize:

> *Hypothesis 1a: Concurrent priming of the concept "achievement"* and other *pictures rated high in arousal and positive valence will create a similar idea fluency during an EBS session.*

> *Hypothesis 1b: Concurrent priming of the concept "achievement" and other pictures rated high in arousal and positive valence will create a similar idea creativity during an EBS session.*

5.2.1. ***Achievement priming and positive priming over time***

In addition to producing similar idea fluency and idea creativity, the time course of the priming is expected to be no different in achievement priming versus priming with positive images. No research has established a difference in length of the priming effect when activating semantic networks as compared to activating a generally positive mood state. Since this priming is delivered in a similar manner to Study 2, the priming effect is expected to be more pronounced in both achievement and positive picture priming towards the end of the ideation session. However, the fluency of ideas will be similar between the two treatments.

Hypothesis 2a: Concurrent priming of the concept of "achievement" will result in similar idea generation as priming positive priming during the first half of an EBS session.

Hypothesis 2b: Concurrent priming of the concept of "achievement" will result in similar idea fluency than positive priming during the last half of an EBS session.

The number of ideas that are highly creative also are expected to be similar in the achievement and positive valence, high arousal priming condition. Both priming conditions will affect ideation later in the concurrent priming session. However, the number of ideas rated highly creative will be similar in the achievement and positive priming conditions. Thus,

Hypothesis 3a: Concurrent priming of the concept of "achievement" will result in similar idea creativity as positive priming during the first half of an EBS session.

Hypothesis 3b: Concurrent priming *of the concept of "achievement" will result in increased idea creativity than neutral priming during the last half of an EBS session.*

5.2.2. *Priming induced changes in psychophysiology*

Since this study was delivered using concurrent priming, the achievement prime is expected to activate the same semantic networks as a priori priming. Therefore, the overall effect on cognition and emotion is expected to be similar in the achievement priming condition. Conversely, the positive priming condition, since there is no semantic thread tying the pictures together, is expected to only affect emotion. Therefore, the positive prime is expected to alter only the emotional state of the participant not their overall attention allocated to the task. The achievement prime is expected to have a similar effect on cognition measured as greater alpha attenuation in the frontal cortices after exposure to the achievement prime when compared to the positive prime. Given the close relationship between frontal alpha-wave activity and attention, I hypothesize:

> *Hypothesis 4: Achievement priming, as compared to positive priming, will increase attention during ideation in an EBS session.*

As noted in study two, repeated exposure to positive pictures has shown to increase positive valence, while repeated exposure to negative pictures has been shown to increase negative valence (Bradley and Lang 1994; Kensinger and Schacter 2006). Therefore, I expect both achievement priming and positive priming to be similar, resulting in positive emotional valence. Increased positive valence can be measured by the corrugator supercilli muscle becoming relatively more *deactivated* following exposure to the prime. In addition, exposure to an achievement and positive prime is expected to increase sympathetic nervous system activation (i.e., increased arousal), resulting in increased skin conductance in subsequent ideation during an EBS session. Therefore, the hypotheses for the effect of concurrent priming on emotional psychophysiological response are:

> *Hypothesis 5a: Achievement priming will result in a physiological response that indicates similar positive valence when compared to the positive prime during ideation in an EBS session.*

> *Hypothesis 5b: Achievement priming will result in a physiological response that indicates similar arousal when compared to the positive prime during ideation in an EBS session.*

5.2.3. *Changes in cognition and emotion over time*

The expected time course of the psychophysiological changes in cognition and emotion are expected to be similar to study two. Specifically, the priming effect will manifest during the latter stages of the task. The EBS session will begin with similar levels of attention, valence, and arousal between achievement and positive priming. As the EBS session continues, the emotional changes in valence and arousal will be observed, specifically there will be higher levels of positive valence and arousal during the latter stages of the task. Levels of attention observed in the achievement priming condition, as measured by alpha attenuation, are expected to be higher than in the positive priming condition, since the positive prime is not expected to activate semantic networks related to the concept of success. Therefore,

Hypothesis 6a: Achievement priming will result in higher positive valence in the last half of an EBS session when compared to the first half of the EBS session.

Hypothesis 6b: Positive priming will result in higher positive valence in the last half of an EBS session when compared to the first half of the EBS session.

Hypothesis 7a: Achievement priming will result in increased arousal in the last half of an EBS session when compared to the first half of the EBS session.

Hypothesis 7b: Positive priming will result in increased arousal in the last half of an EBS session when compared to the first half of the EBS session.

Hypothesis 8a: Achievement priming will result in similar attention, as measured by alpha attenuation in the frontal cortices, than positive priming during ideation in the first half of an EBS session.

Hypothesis 8b: Achievement priming will result in greater attention, as measured by alpha attenuation in the frontal cortices, than positive priming during ideation in the last half of an EBS session.

Study Three: Achievement versus Positive Priming Methodology

5.3.1. *Participants*

Fifty-three students were recruited from an upper-level business school course. The course consisted of juniors and seniors, and participants completed the study for extra credit. Demographic variables were obtained to provide average age and gender distribution. Age ranged from 19 to 28 with the average age being 21.8 years of age. Thirty-two participants (59.3%) were male and 22 participants were female (40.7%).

5.3.2. *Tasks*

The same EBS tasks were used in study two as in study one and study two. There was one 15 minute task on generating ideas to reduce pollution and one 15 minute task on increasing tourism.

5.3.3. *Treatments*

The third study was a repeated measures experiment using concurrent priming with pictures. Each participant received two within subject treatments: achievement priming and positive priming. Participants generated ideas using the simulator from study one and two. Priming was delivered by pictures presented in a banner on the right side of the screen as in study two. Participants in this treatment group generated ideas while they were being primed. The image in the right hand banner updated to a new image every 20 seconds, and there were 30 different pictures presented in each task. The pictures were presented in landscape format with a resolution of 400 x 300 pixels.

The achievement priming condition for concurrent priming consisted of a set of the same set of 30 images oriented towards the concept of "achievement," while the positive priming condition consists of 30 images high in arousal and positive in valence but not related to the concept of achievement. The positive priming images were selected from the International Affective Picture System (IAPS) database (Lang and Bradley 2007). They were images rated by individuals as both high in arousal and positive in valence. Arousal ratings for the achievement-oriented (M = 5.14, S.D. = 0.41) images did not differ significantly from the positive images (M = 5.30, S.D. = 0.45), ($t(58) = 1.44$, $p = .156$). Positive valence for the achievement images did not differ (M = 5.47, S.D. = 0.61) than in the positive priming condition (M = 5.62, S.D. = .52), ($t(58) = 1.03$, $p = .310$).

5.3.4. *Dependent Variables*

The dependent variables were the same as study one and two and consisted of both behavioral and physiological measures.

5.3.4.1. Behavioral Measures

The behavioral measures were the same as Study One. Idea fluency, measured as number of unique ideas generated, and creativity measures were collected. As in study one and two, the creativity measures included assessment of novelty, workability, and relevance to obtain a measure of overall creativity and total number of creative ideas.

5.3.4.2. Physiological Measures

The physiological measures were the same as study one and two and included EEG measures, as well as, psychophysiological measures and skin conductance.

5.3.5. *Control Variables*

The control variables were the same as in Study one and two.

5.3.6. *Procedure*

The procedure of study three was similar to study two. Participants completed the experimental procedure individually after providing informed consent approved by the university’s Institutional Review Board. The experiment took place in an individual lab room at a research institute. The entire research session took approximately 60 minutes. The surveys presented in the experiment were controlled by MediaLab software (Jarvis

2010). The simulator software was developed using a Unity gaming shell.

Again, participants were seated in a high back chair to minimize movement. They used a standard keyboard and mouse. The protocol began with a 10-minute series of personality questionnaires. The experimenter then explained the procedure for attaching the physiological electrodes and fitting the EEG apparatus, answering any questions posed by the participant. After obtaining adequate impedance readings for the EMG and EEG measures, the protocol continued with another brief handedness questionnaire.

The participants were randomly assigned to either the positive or achievement priming condition. In addition, task order was counterbalanced with 27 participants receiving the pollution task first and 30 receiving the tourism task first. Participants then worked on the first EBS task for fifteen minutes. Next they completed a short survey to serve as a "distractor" between treatments. Participants repeated these same steps (priming game, idea generation) for the second priming manipulation and task. The participants were debriefed and the session concluded.

In total, the EEG apparatus was on the participants for approximately 45 minutes, during which the electrodes remained damp with the saline solution. Markers were inserted into the data by the simulation software, indicating when an idea had been entered into the chat room. This allowed for synchronization between the EBS session, EEG and EMG systems. When the discussion simulation was completed, the experimenter removed all physiological data collection sensors. Participants then completed the post-experiment questionnaire. Finally, they were be debriefed, told of the deception, asked not to inform others of the deception, and thanked for their time.

5.3.7. *Manipulation Checks*

Again, it was essential to ensure that participants perceived the simulator as a real team discussion. All participants completed post-session questionnaires that asked if they have noticed anything unusual about the team discussion. A variety of distractor questions (e.g., satisfaction with discussion, perceived effectiveness) were also included to better ensure that manipulation check question did not stand out. Participants that recognized they were not interacting with real people were be removed from the study as failing the manipulation check. Six of the 53 participants recognized they were not interacting with a simulator and were removed from the analysis, leaving 47 participants in the study. This represents a 11.3% of individuals failing the manipulation check, which is in line with prior studies ranging to 10-15% of the subjects failing manipulation checks (Garfield et al. 2001; Heninger et al. 2006).

Study Three: Achievement vs Generic Positive Priming Results

5.4.1. *Behavioral results*

The statistical analyses for the behavioral component of study one were completed in SPSS PASW Statistics 18.0. A repeated-measures GLM was used to examine differences between the achievement and generic positive priming conditions.

5.4.1.1. Idea fluency

Individuals did not differ in the number of ideas produced in the happy or the achievement treatments ($F(1,51) = 1.079$, $p = .304$). The order in which the group received priming treatments did not affect the number of unique ideas generated ($F(1,51) = 3.067$, $p = .086$), nor did the task order for the pollution and tourism task ($F(1,51) = 3.491$, $p = .068$). Therefore, Hypothesis 1a was supported, the concurrent achievement prime led to similar idea generation as the generic positive prime. Table 3.1 shows the means and standard deviations of the number of unique ideas generated in the achievement and generic positive priming conditions.

5.4.1.2. Idea Creativity

Individuals produced a similar number of novel ideas in both the achievement and generic positive priming conditions (F(1,51) = 0.40, p = .530). The order in which the participant received the priming conditions did not affect the number of novel ideas produced (F(1,51) = 2.84, p = .098), nor did the order in which he or she received the pollution or tourism task (F(1,51) = 2.11, p = .152).

Individuals produced a similar number of workable ideas in both the achievement and generic positive priming conditions (F(1,51) = 0.64, p = .427). The order in which the participant received the priming conditions did not affect the number of workable ideas produced (F(1,51) = 1.05, p = .310), nor did task order (F(1,51) = 2.52, p = .119).

Individuals produced a similar number of relevant ideas in both the achievement and generic positive priming conditions (F(1,51) = .46, p = .501). The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,51) = 1.89, p = .175), nor did task order (F(1,51) = 3.21, p = .079).

The findings on novelty, workability, and relevance, taken together, provide support for Hypothesis 1b. Achievement priming and generic positive priming produced similar creativity of ideas. Table 3.1 shows a summary of the means and standard deviations between the achievement and generic positive priming treatments.

Table 3.1 Means, standard deviations, and results of statistical analyses

		Achievement Prime		Positive Prime		F	p-value
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**		
Number of Unique Ideas	54	11.41	4.39	11.89	4.82	1.08	0.304
Number of Novel Ideas	54	3.30	1.21	3.65	1.35	0.40	0.530
Number of Workable Ideas	54	10.91	4.05	11.04	4.33	0.64	0.636
Number of Relevant Ideas	54	9.72	3.53	10.56	3.91	0.46	0.501

5.4.2. ***Achievement and generic positive priming over time: Behavioral Analysis***

5.4.2.1. Idea fluency and time

Individuals produced significantly more ideas in the generic positive priming treatment compared to the achievement treatment during the first half of the EBS session ($F(1,51) = 49.13$, $p < .001$). The effect size was small with a Cohen's $d = .11$. The order in which the participant received the priming conditions did not affect the number of ideas produced in the first half of the EBS session ($F(1,51) = 1.03$, $p = .315$), nor did task order ($F(1,51) = 1.46$, $p = .233$). These findings support the alternate to Hypothesis 2a, the generic positive priming effect appears to have an influence on idea fluency during the first half of the brainstorming session above and beyond the effect of the achievement prime. The means, standard deviations, and results are provided in Table 3.2.

There was no significant difference in idea generation between the achievement and generic positive priming in the last half of the EBS session ($F(1,51) = 1.08$, $p = .305$. The order in which the participant received the priming conditions did not affect the number of ideas produced in the last half of the EBS session ($F(1,51) = 2.17$, $p = .147$), nor did the task order ($F(1,51) = 3.61$, $p = .063$). Therefore, Hypothesis 2b was supported, the priming effect generated by both the achievement and generic positive images resulted in similar idea generation in the last half of the EBS session. The means, standard deviations, and results are provided in Table 3.3.

In addition to the tests of the hypotheses, I also compared the first half of achievement idea fluency against the last half of achievement with a post-hoc pairwise comparison. The number of ideas generated in the first half of an EBS session during the achievement prime was significantly higher than the last half of ideas generated in an

EBS session during the achievement treatment (t(106) = 4.035, p < .001). In addition, the number of ideas produced during the first half of the EBS session in the generic positive priming treatment significantly differed from the number of ideas produced in the last half of the EBS session of the generic positive priming treatment (t(106) = 3.581, p < .001). This indicates that the concurrent achievement and generic positive prime produces a priming effect that has more of an influence on the first half of the EBS session. Despite the early idea generation benefit of the generic positive prime, the two treatments did not differ in idea fluency over the entire EBS session.

5.4.2.2. Idea creativity and time

Individuals produced a greater number of novel ideas following the generic positive priming treatment during the first half of an EBS session when compared to achievement (F(1,51) = 170.62, p < .001). The effect size was small with Cohen's *d* = .30. The order in which the participant received the priming conditions did not affect the number of novel ideas produced (F(1,51) = 1.13, p = .292), nor did the order in which he or she received the pollution or tourism task (F(1,51) = .328, p = .569).

Individuals produced a greater number of workable ideas following the generic positive prime during the first half of an EBS session when compared to achievement (F(1,51) = 513.33, p < .001). The effect size was small with a Cohen's *d* = .07. The order in which the participant received the priming conditions did not affect the number of workable ideas produced (F(1,51) = 2.31, p = .135), nor did task order (F(1,51) = .39, p = .534).

Individuals produced a greater number of relevant ideas following the generic positive prime during the first half of an EBS session when compared to achievement (F(1,51) = 526.27, p < .001). The effect size was small with Cohen's *d* = .24. The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,51) = 1.89, p = .176), nor did task order (F(1,51) = .017, p = .896). These findings support the alternate to Hypothesis 3a, indicating the concurrent prime has an impact during the early stages of the task. The means, standard deviations, and results are provided in Table 3.2.

Individuals produced a similar number of novel ideas during the achievement priming treatment and the generic positive priming treatments during the last half of an EBS session (F(1,51) = 2.87, p = .096). The order in which the participant received the priming conditions did not affect the number of novel ideas produced (F(1,51) = 1.55, p = .219), nor did the order in which he or she received the pollution or tourism task (F(1,51) = .142, p = .707).

Individuals produced a similar number of workable ideas during the achievement and generic positive priming treatment in the last half of an EBS session (F(1,51) = 0.24, p = .628). The order in which the participant received the priming conditions did not affect the number of workable ideas produced (F(1,51) = 2.22, p = .142), nor did task order (F(1,51) = 2.96, p = .091).

Individuals produced a similar number of relevant ideas during the achievement and the generic positive prime in the last half of an EBS session (F(1,51) = 1.87, p = .178). The order in which the participant received the priming conditions did not affect the number of relevant ideas produced (F(1,51) = 2.13, p = .150), nor did task order (F(1,51) = 3.48, p = .068). These findings support Hypothesis 3b and indicate that the achievement and generic positive images produce similar idea creativity in the latter stages of the task. The means, standard deviations, and results are provided in Table 1.3.

Table 3.2 Means, standard deviations, and results of priming time statistical analyses for first half of the EBS session

Measures	N	Achievement Prime First Half		Positive Prime First Half		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	54	6.65	2.23	6.91	2.51	49.13	< 0.001
Number of Novel Ideas	54	2.35	0.90	2.63	0.96	170.62	< 0.001
Number of Workable Ideas	54	6.81	2.38	6.98	2.45	513.33	< 0.001
Number of Relevant Ideas	54	6.19	2.07	6.72	2.41	526.27	< 0.001

Table 3.3 Means, standard deviations, and results of priming time statistical analyses for last half of the EBS session

Measures	n	Achievement Prime Last Half		Positive Prime Last Half		F	p-value
		Mean	Std.	Mean	Std.		
Number of Unique Ideas	54	4.76	2.62	4.98	3.07	1.08	0.305
Number of Novel Ideas	54	0.94	0.66	1.02	0.86	1.55	0.219
Number of Workable Ideas	54	4.10	1.75	4.06	1.97	0.24	0.628
Number of Relevant Ideas	54	3.54	1.56	3.84	1.59	1.87	0.178

5.4.3. *Changes in Cognition*

5.4.3.1. Event-related Spectral Perturbation (ERSP) analysis

Similarly to the first two studies, the *K*-means cluster analysis produced three neurological clusters of interest. These were selected initially according to the number of subjects and ICs represented in each cluster and were supported by visual inspection of the corresponding scalp maps. Due to the idiosyncratic nature of neural activity within each participant, some individuals did not produce independent components in each cluster. Participants which produced many muscular artifacts may have produced ICs that were predominated by the much larger variance created by these muscle movement (and not neural activity).

The first cluster is similar to the other right frontal clusters in study one and two. It is more dispersed than the cluster in study two, however, is very similar to the cluster generated in cluster one. This cluster contained data from 40 subjects and 132 ICs. This cluster appears to be spread across the right frontal lobe with some dispersion to left frontal cortex as well (See Figure 3.1). Like the previous studies, the right frontal activation could be indicative of increased activity in creative regions of the brain. However, these cognitive changes did not manifest in behavioral changes in idea production.

T-tests of the achievement prime and generic positive prime are presented in Figure 3.1, Individuals showed significant alpha attenuation (i.e., increased cognition) (Panel 1) with the achievement prime as compared to the generic positive priming condition (Panel 2). Panel 3 shows areas where they significantly differed. Alpha band differences were detected between 3500ms and 2000ms before the subject entered ideas into the chat simulator. Furthermore, these changes were evident across the alpha frequency band (8-13Hz), showing greater cortical attention after the achievement prime in this region when compared to the generic positive prime. This is indicative of the subjects using more cognitive resources in the creative regions of the brain during the achievement priming condition when compared to the generic positive priming condition.

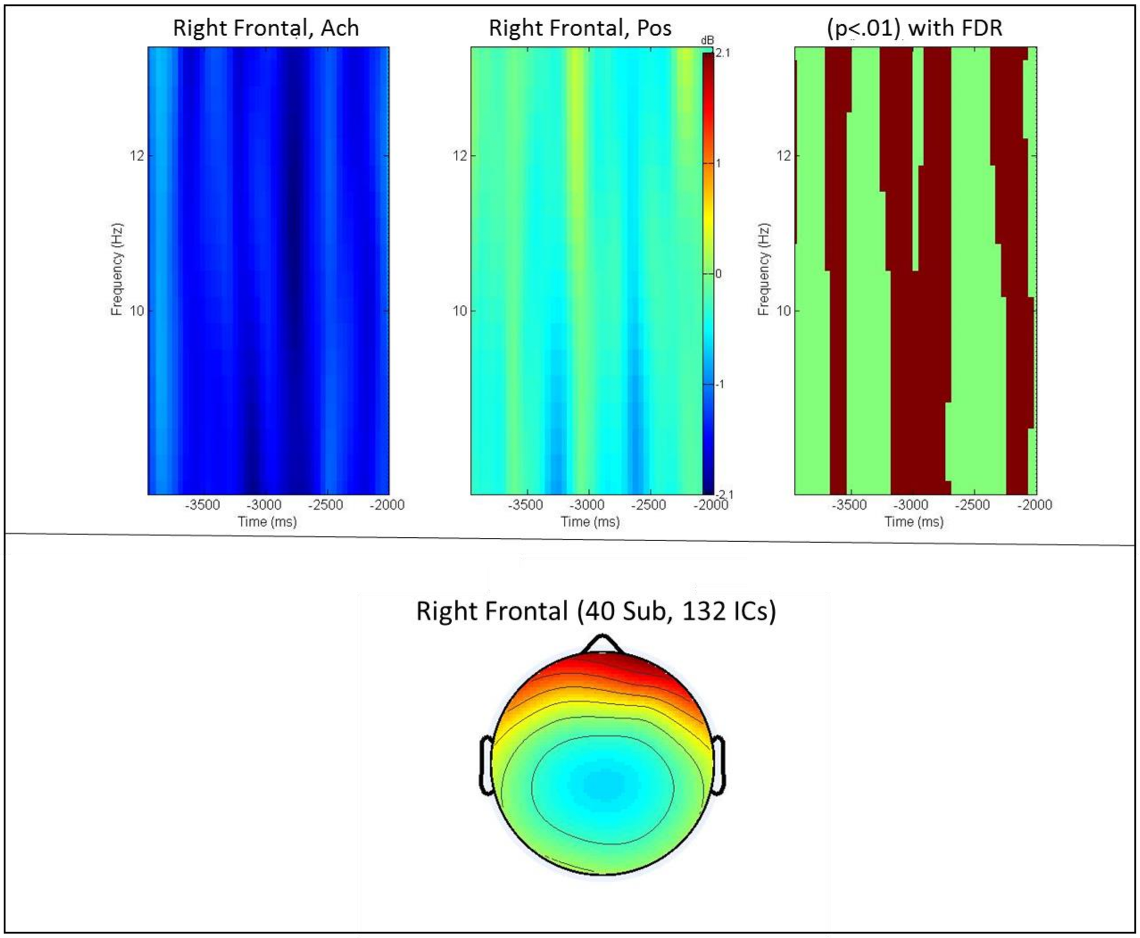

Figure 3.1 ERSP of Right Frontal cluster indicating significant alpha attenuation during ideation during the concurrent achievement prime when compared to the generic positive prime.

The second cluster is unlike the previous two studies. It is a temporal cluster, located directly over the left temporal cortex. Left temporal cortex is where Wernicke's area is located, which is the primary language recognition area of the brain (Scott et al. 2000). This cluster contained data from 38 subjects and 118 ICs (See Figure 3.2). This region is heavily involved in cognitive processing of language.

T-tests of the achievement prime and generic positive prime are presented in Figure 3.2. Panel 3 shows no areas where they significantly differed. This finding indicates that the achievement-oriented and generic positive prime did not comparatively change cognition in the language recognition areas of the brain.

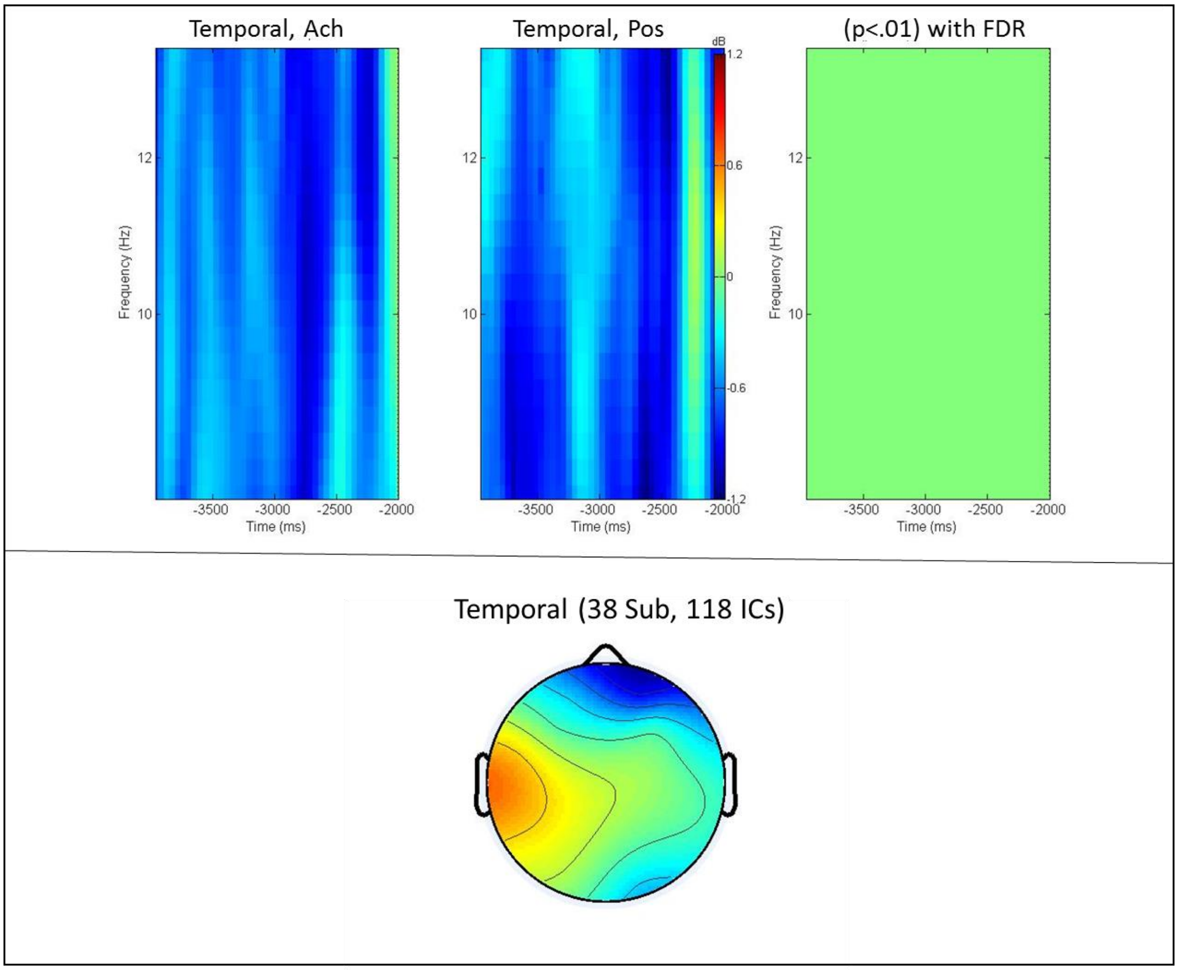

Figure 3.2 ERSP of Left Temporal cluster showing no significant differences between achievement and generic positive priming treatments.

The third cluster is similar to the parietal cluster observed in the previous studies. It is localized to an area posterior to the central sulcus in the parietal lobe. During the concurrent prime, as in study two, the participants were exposed to images as well as the chat room. These images differed between treatments with one set being related to achievement and one set being generic positive images. The parietal lobe is responsible for integrating sensory information and relaying it to frontal regions for further processing. This cluster contained data from 36 subjects and 298 ICs (See Figure 3.3).

T-tests of the achievement prime and generic positive prime are presented in Figure 2.3. Panel 3 shows one small area where they significantly differed. This shows the positive images created slightly more alpha attenuation in this region than the achievement related images. These findings indicate that overall the images in the achievement treatment and the generic positive priming treatment did not significantly differ in the way they were processed in the parietal lobe.

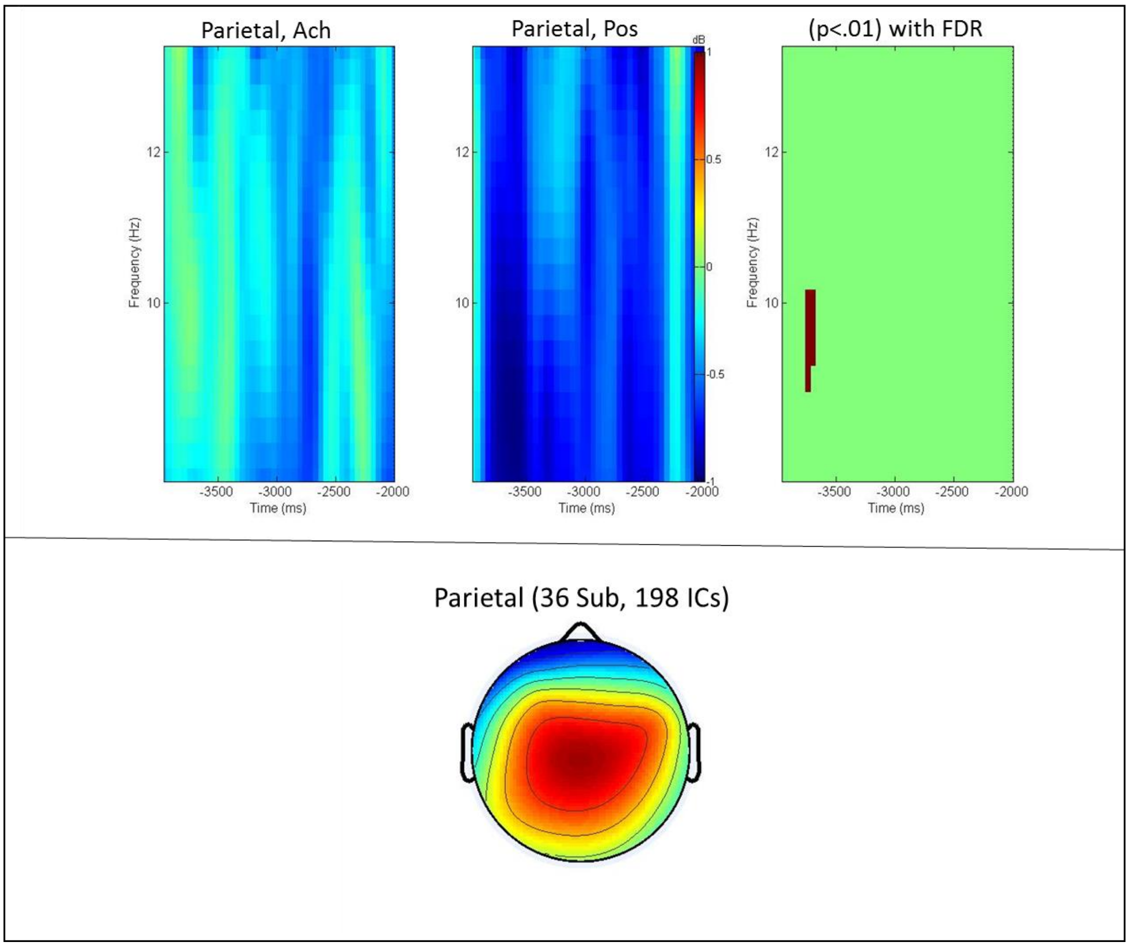

Figure 3.3 ERSP of Parietal cluster indicating similar alpha attenuation in both the achievement and generic positive priming treatments.

5.4.3.2. Cognitive changes over time

In examining the changes in cognition due to the achievement priming effect in an EBS session, it is important to examine the cognitive changes in ideation over time. To do this, the same clusters from the full analysis were used and ideas were coded into occurring in the first half of the EBS session or the last half of the EBS session. ERSPs were generated for each of the clusters for the first and last half of the EBS session.

The right frontal cluster time analysis showed that no significant differences were observed between achievement and generic positive priming during the first half of the EBS session. A small area of significance was observed in the last half of the session between the two achievement and generic positive priming treatments with achievement priming showing greater alpha attenuation (i.e., increased cognitive activity). While the images do look different in the first and last half, there likely was not enough statistical power to uncover the differences, due to the lower amount of ideas in the both halves. Therefore, Hypotheses 8a and 8b are not supported. The ERSPs are shown in Figure 3.4.

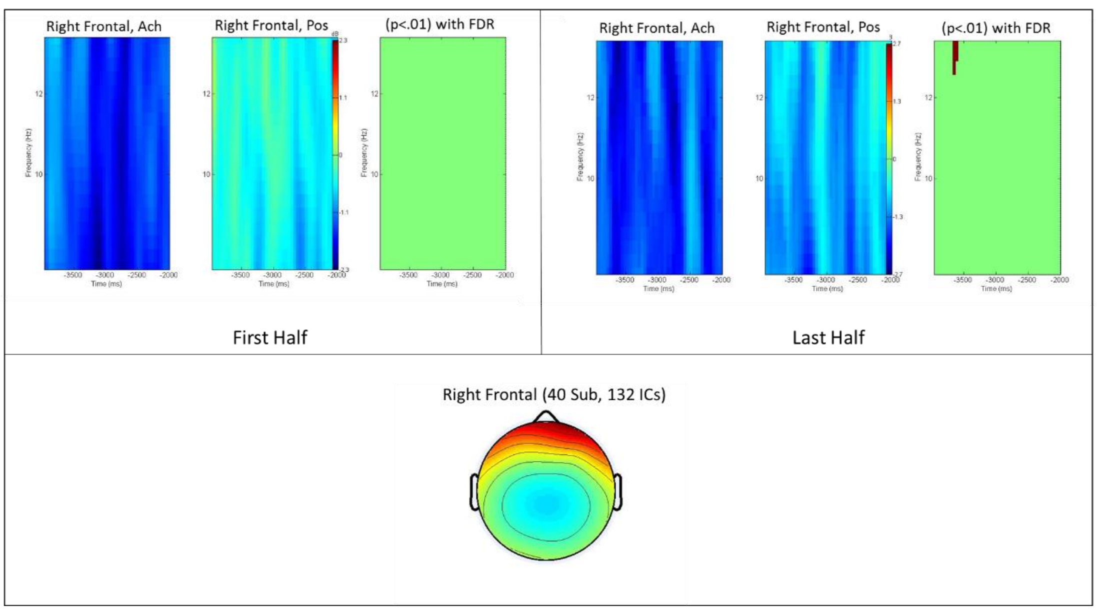

Figure 3.4 ERSP of Right Frontal cluster indicating no significant differences in alpha attenuation in the first half and little significant difference in the last half of the EBS session.

The temporal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and generic positive priming treatments during the first half of the EBS session. Furthermore, some significant differences were observed around 2700ms to 2000ms across the alpha frequency band with the achievement prime showing more alpha attenuation than the generic positive priming condition in the last half of the EBS session. The ERSPs are shown in Figure 3.5. This finding indicates that in the speech recognition region of the brain, there was only slight differences observed in the last half of the EBS session between the achievement and generic positive prime. The differences observed in the latter half could be a result of individuals recognizing the common theme of “achievement” in the images, which would likely activate semantic networks associated with the concept of achievement.

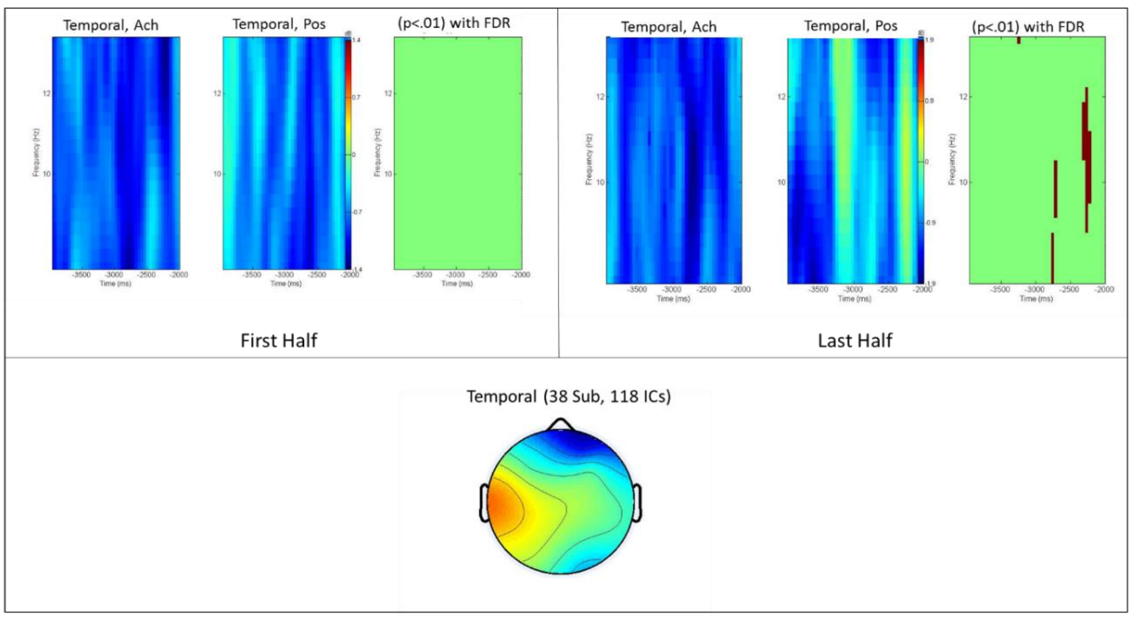

Figure 3.5 ERSP of Left Temporal cluster showing no significant differences in cognition during the first half and subtle differences in alpha attenuation in the last half of the EBS session.

The parietal cluster time analysis showed no significant differences occurred across the alpha frequency spectrum between the achievement and generic positive priming treatments during the first half of the EBS session. Furthermore, no significant differences were observed during the second half of the EBS session. The ERSPs are shown in Figure 3.6.

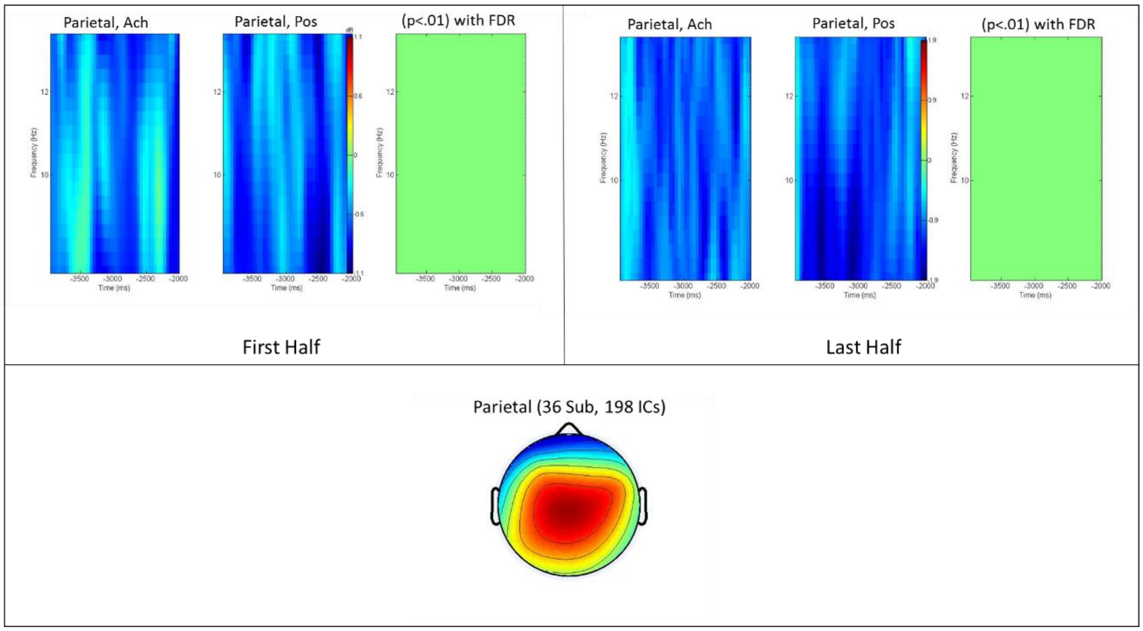

Figure 3.6 ERSP of Parietal cluster showing no significant differences in cognition during the first and last half of the EBS session.

These EEG results, taken together, indicate that the achievement prime significantly affects cognition in right frontal cortex, much like the previous studies. There were minimal significant differences observed in Wernicke's area, indicating a potential association of the semantic network "achievement" activated by the achievement prime. Finally, the third cluster shows subtle significant differences over the entire EBS session, but not when taken at the first or last half of the EBS session, likely due to a lack of statistical power after the ideas were split.

5.4.4. ***Changes in Emotion***

The psychophysiological measures utilized in this study were analyzed using hierarchical linear modeling (HLM). A two-level model was created with the psychophysiological measure at the first-level. A 20-second average of skin conductance and corrugator activation was taken, representing 10 seconds before the subject entered an idea and the 10 seconds after a subject entered an idea. The treatment and whether the

idea was in the first or second half of the chat session was included as indicators in the HLM model. The second-level of the HLM included an indicator representing the subject number.

For skin, the results do not indicate a main effect of achievement (b = .053, p = .463). This indicates that the concurrent prime resulted in no different arousal between achievement and generic positive treatments during the EBS session. Similarly, corrugator activation, a measure of positive emotional valence, did not significantly differ between the concurrent achievement and generic positive priming condition (b = -.238, p = .229). Therefore Hypotheses 5a and 5b are supported, similar arousal and valence was observed in the achievement and generic positive priming treatments. A table of means and beta coefficients is provided in Table 3.4.

Table 3.4 Means, standard deviations, and results of HLM statistical analyses for skin conductance and corrugator

		Achievement Prime		**Positive Prime**		**B**	**p-value**
Measures	**N**	**Mean**	**Std.**	**Mean**	**Std.**		
Skin Average	50	1.68	1.39	1.70	1.33	0.053	0.463
Corrugator Average	50	0.66	0.85	0.90	1.63	-0.238	0.229

5.4.4.1. Emotional changes over time

Further investigating the route through which the achievement and generic positive prime influence idea generation, it is important to examine differences over time during the EBS session. HLM was used to observe these changes in emotion between achievement and generic positive priming during ideation in the first half and the last half of the EBS session.

For skin conductance, the measure of arousal, no main effect of time was observed (b = -1.19, p = .234). Furthermore, the interaction of treatment and half was not significant (b = 0.05, p = .627). Therefore, Hypotheses 6a and 6b are supported. For corrugator, the measure of positive valence, no significant differences were observed in the first or last half of the EBS session (b = -0.01, p = 0.882). Furthermore, there was no interaction observed between treatment and first and last half of the EBS session (b = -0.095, p = 0.295). Therefore, achievement and generic positive priming did not create changes in emotional state of the subjects in either arousal or valence during ideation in the EBS session. Therefore, Hypotheses 7a and 7b are supported. A table of means for the first and last half of the ideas generated in the EBS session is provided in Table 3.5.

Table 3.5 Means and standard deviations for skin conductance and corrugator in the first and last half of the EBS session

		Achievement Prime		Positive Prime	
Measures	**n**	**Mean**	**Std.**	**Mean**	**Std.**
Skin Average: First Half	50	1.75	1.41	1.72	1.27
Skin Average: Last Half	50	1.57	1.34	1.68	1.42
Corrugator Average: First Half	50	0.76	0.96	0.90	1.52
Corrugator Average: Last Half	50	0.53	0.66	0.92	1.77

Study Three: Discussion and Conclusion

This study examined further the impact of the “achievement” oriented prime. The goal of this study was to examine whether a generic positive prime would have a similar impact on idea generation and creativity as the achievement prime. Furthermore, it seeks to establish whether the generic positive prime causes cognitive and emotional changes that are similar to the achievement prime or if it works on cognition and emotion in some other manner.

The behavioral findings indicate that there were no significant difference in idea fluency or creativity associated with the achievement-oriented prime when compared to the generic positive picture prime. However, significant changes in cognition were observed for the achievement prime in the same right frontal region as studies one and two. These findings suggest that, when compared to generic positive images, achievement priming still impacts cognition an area of the brain related to creativity. This finding was consistent across all three studies The generic positive prime, on the other hand, has similar behavioral changes but, cognitively, these changes do not manifest in the same way as the achievement prime, perhaps working through another route.

Looking deeper into the behavioral findings indicate that the generic positive prime has significantly more ideas generated in the first half of the EBS session. Therefore, the generic positive prime provides a more immediate payoff in increasing the number of ideas generated in the first half of the EBS session. There is no significant differences between the images in the last half of the EBS session, which indicates that the achievement prime eventually takes hold. The main difference between the two sets of priming images is the common thread of achievement in the achievement priming condition. It is likely that it takes more time for the individual to subconsciously pick up on this thread (requiring greater cognition), which is potentially why we see the cognitive changes occur later in the EBS session in study two. The time analysis for cognition in study three did not show significant differences between achievement and generic positive images, however, it is possible that this was due in part to a lack of statistical power, since the ERSP pictures appear to show more alpha attenuation in the achievement condition.

The hypotheses for this study asserted that the changes induced by the achievement prime would be through the cognitive route and the changes from the generic positive prime would be through the emotional route. This study did not find support for changes in arousal or positive valence as a result of the generic positive prime. It is likely that the generic positive prime changes emotion or cognition in a way that was not detected in this study. More research is needed to understand how the generic positive prime works. For example, it is possible that a change in the overarching mood state was not evident in down-stream psychophysiological measurements. While there was no support to indicate that the generic positive prime occurred through the emotional route, all three studies support that achievement-oriented priming occurs through the cognitive route, specifically changing cognition in right prefrontal cortex, which is an area of the brain associated with creativity. These changes result in increased idea fluency and creativity when compared to the neutral prime but not the generic positive prime. More research is needed to understand how the generic positive prime influences idea fluency and creativity.

DISCUSSION AND IMPLICATIONS

This dissertation provides evidence that supraliminal priming creates changes in cognition that are associated with increased idea fluency and creativity. In study one, I found that a priori priming of achievement increased the number and quality of ideas generated in subsequent EBS sessions. These changes were associated with changes along the cognitive route that indicate more cognition is occurring in a region of the brain known to be associated with creativity. Study two conceptualized and used a concurrent achievement prime that had been integrated into the EBS tool. The concurrent prime increases both idea fluency and creativity. Similar changes in cognition were recognized during the concurrent prime in the EBS session. While individuals generated ideas, there was an increase in cognition in creative centers of the brain. Study three, contrasted an achievement oriented prime against a generic positive prime. This study showed there were no overall differences in idea fluency or creativity between achievement and generic positive priming, but did show there were differences in cognition resulting from the achievement prime that were similar to study one and two (i.e., creative centers of the brain were more active in achievement priming than generic positive priming).

While changes in cognition were observed across all three studies, there were no changes in emotional state observed in any of the three studies. Emotional changes induced by achievement priming is possible in the a priori priming condition, but these changes would have been transient and were no longer evident once the individual was generating ideas in the EBS session. Similarly during ideation in concurrent priming, in studies two and three, no differences were evident during ideation. This does not preclude changes in emotion that might have happened outside of ideation but, as in study one, these changes were not evident during ideation.

The time course of the a priori priming effect appears to be similar to expectations, an initial priming effect that wears off as the session progresses. However, during concurrent priming, it appears that the impact on behavior occurs earlier than expected, while cognitive differences are observed in the last half of the EBS session.

Taken together, the concurrent prime produces a priming effect that results in increased idea fluency and creativity when compared to a placebo prime. In addition, both a priori and concurrent primes result in changes in cognition in right frontal cortex. However, the concurrent prime remains more practical for the organization because it does not require the 5-8 minute a priori priming session before every brainstorming session. Utilization of concurrent, achievement priming within the organization can result in greater idea fluency and creativity over previous EBS systems, resulting in several implications for research and practice.

Implications for Research

This dissertation shows that priming for achievement improves an individual's idea fluency and creativity in subsequent team brainstorming sessions. Furthermore, it shows that the achievement prime can be done concurrently and integrated into the EBS tool. The use of neurophysiological and psychophysiological tools in this study were able to help identify the changes in cognition and emotion that correspond to the increase in idea fluency and creativity. These tools showed that the changes in ideation as a result of the achievement prime most closely corresponded to cognitive changes in the right prefrontal cortex. This area of cortex has been shown to be closely linked to creativity on generative tasks. I believe this study has a number of implications for research.

First and foremost, I believe this study opens the door for future research on how best to design systems to enhance subconscious cognition. The findings of this study show that our current EBS tools can be improved in such a way that *enhances* performance. In this specific context, adding a banner to the EBS tool that provides pictures of achievement improves ideation performance of an individual working in an EBS team. However, these findings are not confined to the EBS tool. Similar research could help uncover ways to design other collaboration systems to improve creativity or otherwise enhance cognitive performance. This is particularly important for studies that have shown that virtual team performance is somehow limited by individual or group cognition (Dennis 1996; Minas et al. 2014).

Second, the concurrent priming results can further the EBS research stream by allowing it to further explore the use of priming *within* the interface to enhance cognitive performance of the teams. It is possible that it is “not one prime fits all,” in that other concepts may be primed in order to increase performance that is more task specific. For example, concepts of “mindfulness,” “attentiveness,” and “rudeness” have all been found to affect subsequent behavior in previous studies (Bargh and Chartrand 2000). Therefore, there might be certain EBS tasks that benefit from a prime other than the achievement or generic positive prime. Research can delineate if there is a required fit between the prime and the EBS task given to the virtual team by establishing a framework of EBS tasks and matching them to a framework of EBS primes.

Third, this study contributes to the literature of individual cognition on virtual team conveyance tasks (i.e., EBS). It shows that an individual, primed with the concept of achievement, develops more ideas than when he/she is exposed to an achievement prime. This further establishes the importance of individual cognition on overall idea generation of the group. However, since this study used a simulator, it did not examine if the individual level changes propagate out to the entire team. Previous studies have primed all individuals within a virtual team and found that a priori priming influences overall team ideation (Dennis et al. 2013), yet it has not examined if priming of the entire team is necessary to develop the overall effect. If individual level changes propagate to the entire team (as a result of one idea sparking an idea in another), then research could further examine if priming various team members with different concepts (i.e., achievement, mindfulness, rudeness), results in an overall effect that is greater than any single prime.

Research on designing systems to enhance cognition should not be limited to collaboration. Business analytics research, for example, is focusing on how best to visualize big data in a way that best enables the user to process the information (Keim et al. 2013). Neuroimaging and psychophysiology tools utilized in this study can also be used to uncover which visualization technique provides the greatest outcome in terms of cognitive processing of the information. These insights can aid in the design of systems employed in business analytics.

Similarly, the usability research stream can benefit by employing these techniques to explore information processing and emotions resulting from different systems. Whether the findings apply to website design or system design, insights from neuroimaging studies can examine how cognition or emotion is changed by different systems and how these changes relate to usability ratings by users. Once these changes are understood, they can be leveraged to employ systems that help optimize user productivity and satisfaction.

In the systems analysis and design literature, there is much research on cognition in systems analysts when evaluating schema and debugging problematic code. EEG could be utilized to better understand where the cognitive breakdowns occur for analysts. Establishing the sources of cognitive "traps" for analysts can enable the design of diagrams that helps alleviate the high demand on cognitive resources of analysts. Similarly, understanding the sources of greatest cognitive effort during debugging of code can help us further understand how to instruct analysts to approach fixing problematic code.

In addition to these methods helping several areas of the IS field, the neurophysiological findings in this study are interesting in their own right. First, we were able to establish with a low-density EEG system that cognitive changes in the alpha spectrum (closely tied to attention and cognitive load) occur in right frontal cortex for the achievement prime in all three studies. This finding provides a consistent view of how Bargh et al's conceptualization of achievement priming affects cognition. Specifically, by increasing the degree to which creative regions of the brain are involved during ideation. More research is needed, however, to establish if this finding is specific to ideation or if it affects other behaviors that have been shown to be affected by the achievement prime (e.g., performance on high-stakes testing, performance on creativity tasks, etc). It is possible that the consistency of these findings across the three studies might indicate that the mechanism through which the achievement prime works in cases outside of idea generation is also by creating greater activation of right prefrontal cortex. Overall, these findings provide evidence that the achievement prime works by creating a cognitive response that persists for some time then, eventually, returns to baseline.

Finally, this study helps shift the focus of collaboration literature to individual cognition. One primary focus of collaboration research has been on virtual team dynamics and how to facilitate communication among the team through technology. However, only recently has attention been focused on the importance of helping facilitate the individual to perform optimally, this improving performance of the overall team. The findings of this study help underscore the importance of individual cognitive differences and their ability to affect individual performance outcomes (i.e., idea generation). This dissertation builds on Dennis et al (2013), in that it provides a source of the team performance gains observed following a priori achievement priming, specifically that it impacts individual cognition by increasing cognition in creative centers of the brain. Therefore, other areas of collaboration should be further examined to see if previously unexplained performance gains at the team level are a result in individual cognitive changes. These changes could be further examined using NeuroIS to further investigate how to best facilitate further productivity gains.

Implications for Practice

This dissertation has several implications for organizations. First, the finding that the concurrent prime improves brainstorming similarly to a priori priming indicates that designers of EBS technology should consider incorporating concurrent achievement priming into their brainstorming tools. This will allow the EBS software to be utilized by organizations to improve brainstorming results. Within the organization, managers should consider using EBS tools with the concurrent achievement prime embedded to improve brainstorming results of virtual teams, thereby increasing the number of ideas generated on a problem, as well as, increasing the number of creative ideas generated in brainstorming sessions.

Furthermore, instead of building a priori priming into organizational activities, which requires a 5 to 10 minute priming session before the activity, managers can apply the concurrent priming findings to areas outside of EBS. For example, corporate presentations could include priming that is integrated into the presentation either through the presentation slides itself, or in some other fashion. Achievement images have been shown to increase cognition in creative regions of the brain, so for during exercises that are part of creative processes in organizations, a concurrent prime with pictures can be utilized to enhance the creative output of the individuals and/or teams.

Finally, there is an important implication for IT software developers. Specifically, utilizing the tools of cognitive neuroscience, they can better understand how to create software that ensures increased performance outcomes for their clients. The software can then be marketed as designed to increase productivity through the application of cognitive neuroscience. Only recently have corporations begun to venture into the market of finding ways to enhance cognition (e.g., Luminosity.com). However, software developers can create their EBS (or other) software in a way that has been shown to enhance performance on generative tasks by increasing creative output of the groups. This software has increased potential for gaining market share in the organizational setting because it employs a novel software development technique.

Conclusion

The goal of this dissertation was to investigate new opportunities for IS design, namely to begin to think about how subconscious cognition can be influenced by subtle design interventions that improve performance. While the implications of this dissertation are directly applicable to design of the EBS technology, future studies can examine the use of priming in other collaboration tools (e.g., video conferencing, email, social networking). There may also be implications for the design of other forms of technology. The use of NeuroIS to more fully understand information processing in teams also enhanced the collaboration literature by showing that the priming effect worked by altering cognition, which in turn was associated with increased ideation. This can enhance our understanding of which aspects of team interactions have the biggest "bang for their buck" from a cognitive standpoint. Overall, these studies provide evidence for improving EBS system design in a way that increases idea fluency and creativity. It also provides the field with an opportunity to begin examining how to use NeuroIS to begin to develop systems that enhance the subconscious.

APPENDIX A: PILOT STUDY SUMMARY

The pilot phase of this dissertation have been completed. The first stage of the dissertation involved validating the images chosen for achievement were, in fact, rated as being related to the concept of "achievement." A group of 25 students were assigned to computers wherein a set of 80 images were randomly presented. Forty of the images were picked by experts as "related to achievement," while 40 images were picked as "neutral" and designed to have no effect. After viewing the image for 10 seconds, the students were asked to rate the image on achievement, arousal, and valence (how positive or negative the image made them feel). Thirty images were chosen from each set of "achievement" and "neutral" images based on their achievement ratings. The achievement and neutral images significantly differed on achievement ($t(58) = 7.87$, $p < .001$), arousal ($t(58) = 4.71$, $p < .001$), and valence ($t(58) = 3.75$, $p < .001$). The achievement images are therefore significantly more related to achievement then the neutral images. Furthermore, they provide greater excitation and are more positive than the neutral images.

The main pilot study used the validated images in a "concurrent" prime. The images were displayed in landscape format along a banner on the right hand side of the screen. A standard brainstorming window was provided on the rest of the screen and participants performed an individual brainstorming task on ways to reduce pollution or increase tourism for 15 minutes. There were two treatments. The first treatment was a fifteen minute individual EBS with concurrent, achievement priming in the right side banner. The second treatment was a fifteen minute individual EBS with concurrent, neutral priming in the right side banner. Each participant received both treatments, counterbalanced on EBS task and priming across participants. Forty-three subjects participated in the pilot. Individuals generated significantly more ideas when exposed to the concurrent, achievement prime than the neutral prime ($F(1,40) = 4.77$, $p = .035$). The order in which the individual received priming conditions did not affect the number of ideas produced ($F(1,40) = 0.67$, $p = .417$), nor did the task order ($F(1,40) = 2.94$, $p = .094$). This pilot provides evidence that the concurrent prime will behave similarly to the a priori prime in an EBS session.

APPENDIX B: EEG DATA COLLECTION AND ANALYSIS

Analysis for EEG data involves a multi-step process of data cleansing and statistical analysis. This appendix gives an overview of each step in the process. The data analysis will follow an outline provided by Delorme and Makeig (2013) on the EEGLAB Documentation Wiki. This analysis was previously completed in Minas et al (2014). The figures used as examples in this appendix are taken from the data analysis I completed in this previous study.

Data Collection Software

The data will be collected via Emotiv TestBench Software Version 1.5.0.3. This software enables verification of impedances from the electrodes, as well as, ongoing monitoring of data collection from each of the 14-channels throughout the EEG session. After the EEG data has been collected, the data can be exported via the Emotiv Testbench software from the proprietary .EDF file format to a generic .CSV format. Comma-separated value format can be imported into MatLab for analysis.

Data Analysis

The data will be analyzed using the EEGLAB v11 toolbox for MatLab. Matlab version 2010b will be used for the analysis. EEG data in .CSV format will be imported into MatLab and loaded into the EEGLAB toolbox for subsequent cleaning and analysis.

Step One: Individual-Level Artifact Removal

Data collected using EEG is subject to artifacts generated by muscle movements, cardiac activity, eye blink, ambient electrical activity in the room among others. For example, the muscle artifact is introduced because the electrical signals generated by muscle movements in the face and scalp are much larger than those generated by neurons in the cortex. The EEG electrodes on the scalp detect this activity, resulting in the muscle artifact. Potentially the most problematic artifact is the ocular artifact (i.e., eye blink). The ocular artifact occurs because there is a voltage differential present between the front and back of the eye (Croft and Barry 2000). When an individual blinks the eye rotates up, resulting in an electrical gradient change that is detected by the frontal EEG electrodes (Croft and Barry 2000). An example of the ocular artifact is presented in Figure 1. The artifact is apparent on lines 1-Fp1 and 1-Fp2 between 00:00:14 and 00:00:15 seconds and again between 00:00:16 and 00:00:17 seconds. These artifacts are problematic because they decrease the signal-to-noise ratio, obscuring results.

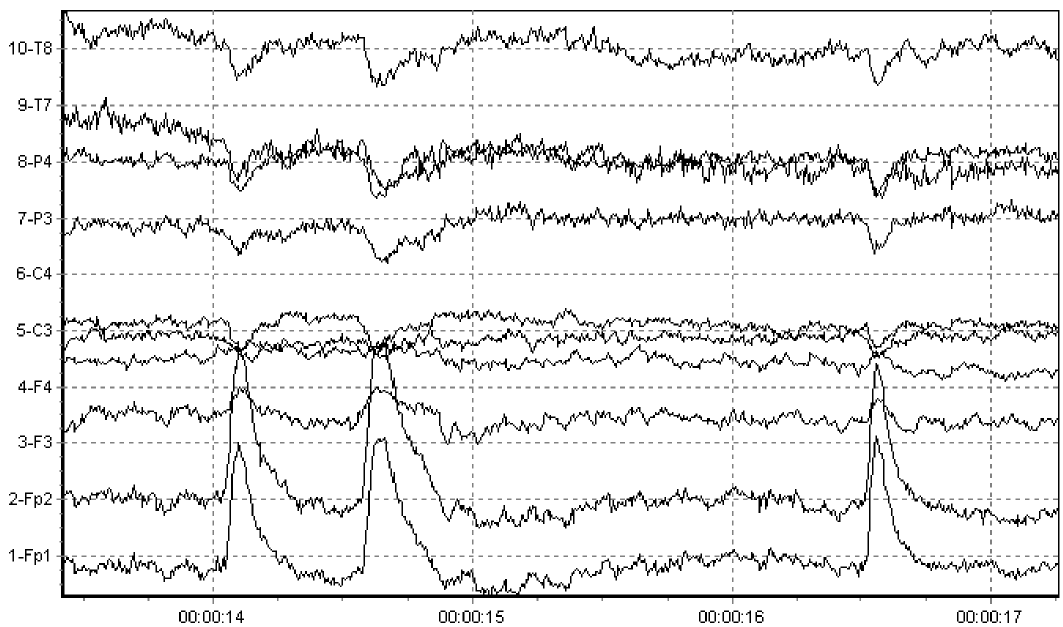

Figure B.1. Example of the Ocular Artifact in EEG Data.

To account for these artifacts, the data must be closely examined. In this study, the data will be cleaned of artifacts in EEGLAB by two methods: visual inspection and algorithm. During visual inspection, an analyst will scroll through the trials (i.e., the six seconds prior to typing an idea in the EBS chat window) and remove trials wherein artifacts are present. A conservative approach will be taken during visual inspection and questionable or borderline trials will be removed. The next step will be to reject trials based on automatic detection using algorithms provided within EEGLAB. These algorithms use channel statistics to detect large deviations from baseline measurement and mark the problematic trials for removal (Delorme and Makeig 2013). “Bad” trials are defined as having Gaussian distributions that are beyond a chosen threshold from the other trials. The algorithm can use probability or kurtosis to mark trials for rejection. Probability will be used in this dissertation, and trials with voltages three standard deviations more than baseline will be removed.

Cleaning the data by trials will remove trials with artifacts present. However, occasionally an entire electrode will not have usable data for the entire duration of the channel. This happens in two ways, first the electrode may not have sufficient contact with the surface of the scalp, resulting in unreliable data from that channel. Second, the connection of the electrode to the Emotiv system may not have a secure connection with the device. EEGLAB provides an algorithm to detect bad channels as well, using a similar method as the bad trial detection. Electrodes that are far away from the normal distribution of values in the other channels will be marked for removal.

Step Two: Independent Components Analysis

The next step in data analysis is to complete an Independent Component Analysis (ICA) of the data. Generically, an ICA is similar to a principal components analysis with the main difference being the orthogonality constraint is relaxed during an ICA. In EEG< an ICA changes the basis of the data from a single channel on the scalp to a so-called virtual channel basis (Delorme and Makeig 2013). In a signal scalp channel recording, the data is made up of the summed electrical voltages detected at the scalp in relation to a reference electrode. However, after an ICA decomposition is performed, the “virtual channel” represents a pattern of electricity present across all the electrodes on the scalp (Delorme and Makeig 2013). Practically, this is done by assigning a weight to each electrode that represents the level of activity present in that component. Each ICA component represents the summation of all the electrodes multiplied by their respective ICA weight, which produces a pattern of activation across the scalp.

The ICA decomposition produces patterns of activation that are the most temporally independent signals available in the dataset (Delorme and Makeig 2013). In the case of the Emotiv system, this would provide 14 distinct patterns of activation across the scalp (i.e., one per electrode in the data set). Information sources represent activity from one or more cortical patches (Delorme and Makeig 2013). ICA can also produce components that represent specific artifacts, such as the ocular artifact (Delorme and Makeig 2013). These artifacts can be removed after ICA decomposition. However, if they have been removed prior to ICA decomposition, most components will represent neuronal activity. ICA decompositions will be done in EEGLAB and will produce approximately 14 components (less than 14 if electrodes were removed from analysis during data cleansing) per participant. An example of an ICA decomposition is provided in Figure 2. In Figure 2, one can see each component does not represent a single electrode but, rather, a distribution of various levels of activity (indicated by hot and cold colors) across the scalp.

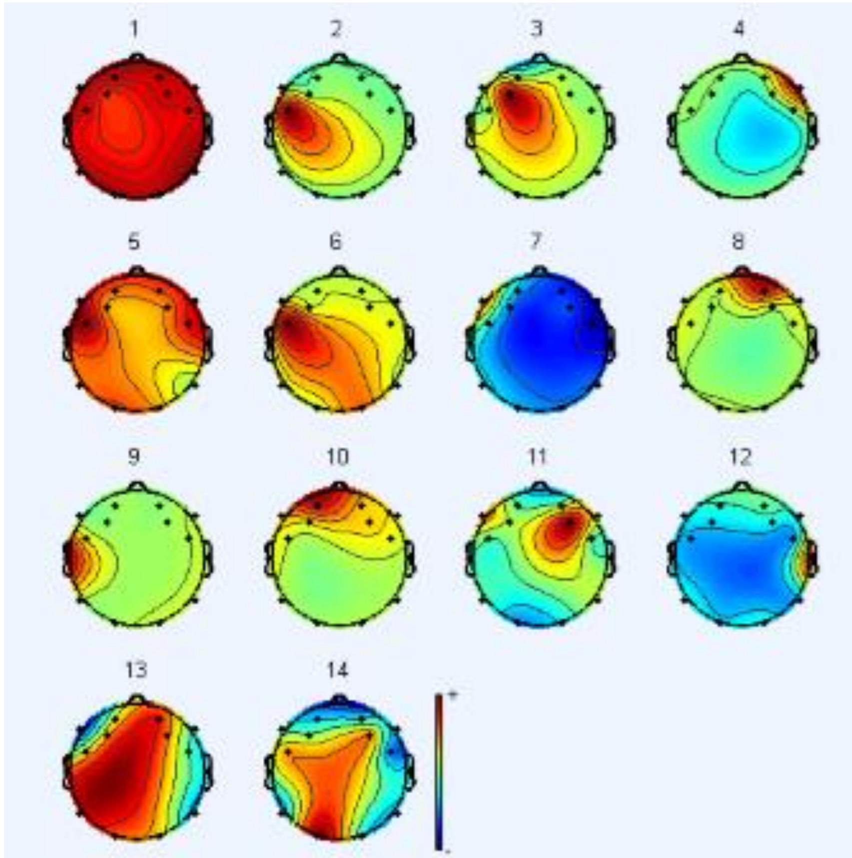

Figure B.2: ICA decomposition for individual with 14 independent components identified

Step Three: Group Level Cluster Analysis

After the ICA weights have been obtained for *each* participant, a cluster analysis is performed on the data for *all* subjects. The cluster analysis finds similarities among the ICA components across subjects and groups the similar clusters together. The cluster analysis can cluster using a *k*-means algorithm based upon data within each ICA component (e.g., dipole locations, spectra, ERPs, scalp maps). The result provided in a set of clusters that represent similar patterns of brain activity between subjects (see, for example, Figure 3). In most cases there will also be clusters with participants that have highly idiosyncratic brain activity. These can be identified by a low number of subjects clustering on the identified cluster (e.g., Cls 12 in Figure 3 has only 1 subjected “1Ss” with 13 independent components in the cluster "13 ICs"). Clusters that have a high number of subjects and independent components, and are identified as neural, are selected for further analysis (e.g., Cls 3 in Figure 3).

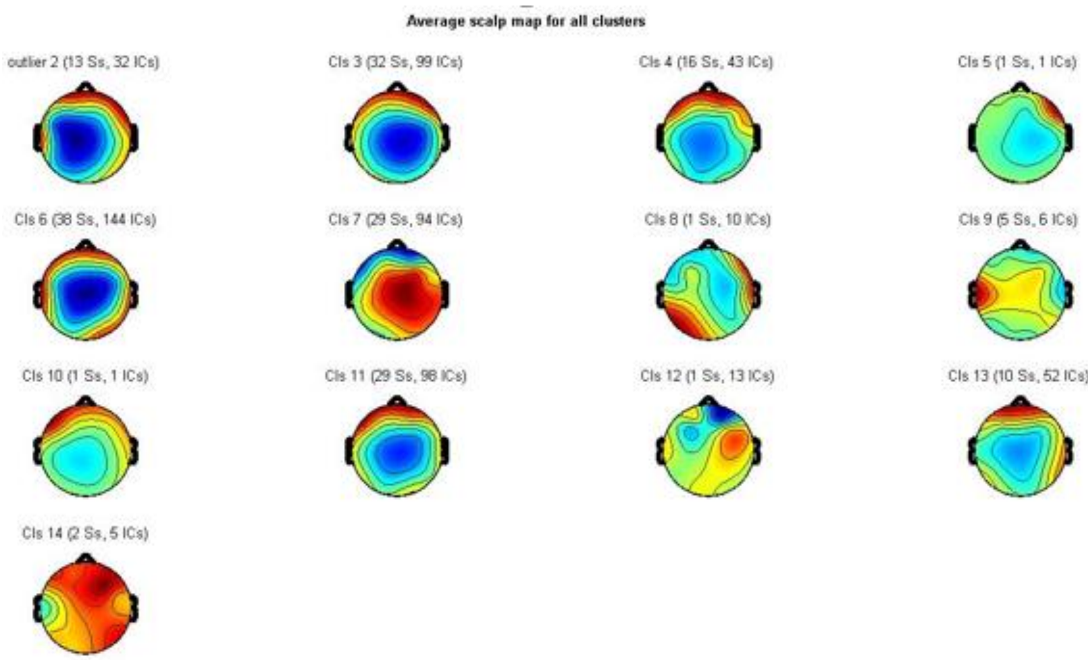

Figure B.3: Example from Minas et al (2014) of cluster analysis results

Step 4: Event Related Spectral Perturbation and statistical analysis of clusters

The final step in the EEG analysis is to run statistical tests on the clusters to calculate significant differences. In these datasets, trials will be labelled as achievement or neutral priming for significance testing. In addition, ideas will be labelled with which time window and treatment the idea was generated (e.g., first third, achievement). Event related spectral perturbation (ERSP) will be used to analyze frequency changes during ideation within each cluster. ERSP is a technique that identifies event related shifts in the power spectrum and inter-trial coherence (Makeig 1993). In ERSP, changes in log power are calculated across a requested frequency range (e.g., alpha 8-13Hz) over a selected time window. Large increases or decreases in power in a frequency during a certain time interval indicates changes in the underlying neural activity in that frequency band.

In EEGLAB, ANOVAs can be performed on ERSPs across datasets and conditions. The ANOVAs provide areas in which there are significant differences in a frequency band at a specific time. The false discovery rate (FDR) can be used to correct for multiple comparisons (Delorme and Makeig 2013). In FDR a corrected threshold is applied to all p-values. FDR is a common correction used in neuroimaging and is considered conservative, although not as conservative as the Bonferoni correction (Delorme and Makeig 2013). The ERSP ANOVA provides output shown in Figure 4. In this example, an omnibus test is completed across five conditions. The five panels on the left indicate the log power at each frequency level across a 3 second time window. The panel on the far right indicates the areas of significance ($p < .01$ with FDR) in red across the frequency band (y-axis) and time (x-axis). The bottom picture shows a scalp map of the cluster from which the ERSP is generated. This indicates, in hot colors, the electrodes that most contributed to this cluster.

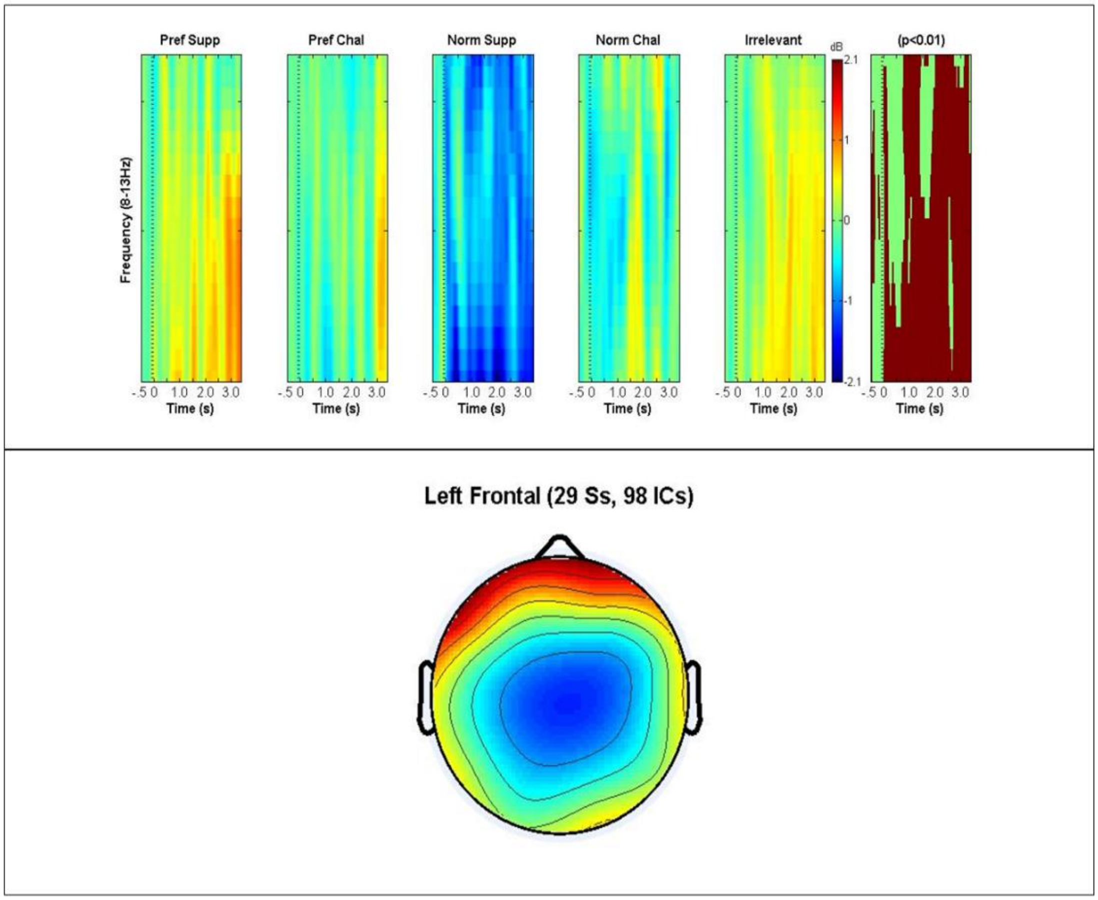

Figure B.4: ERSP and scalp map from Minas et al (2014)

Finally, after the omnibus test is completed, post-hoc pairwise comparisons can be generated to see which conditions are significantly different. In Figure 6, the four left-most panels are compared to the panel "Irrelevant." Significant differences at p < .01 with FDR are shown in red every third panel. In boxes A and B, there are no significant differences between the conditions. However, as is apparent in box C, the majority of significant differences observed in this cluster are driven by a statistically significant difference between the data collected during the "Norm Supp" condition and "Irrelevant" condition. These results indicate significant differences in brain activity in the alpha frequency band between 0 and 3 seconds after stimulus onset (time 0). More specifically, the blue color in the left panel of box C is indicative of alpha attenuation (i.e., more attention) during this condition, and these results are significantly different than the alpha levels observed in the “Irrelevant” condition.

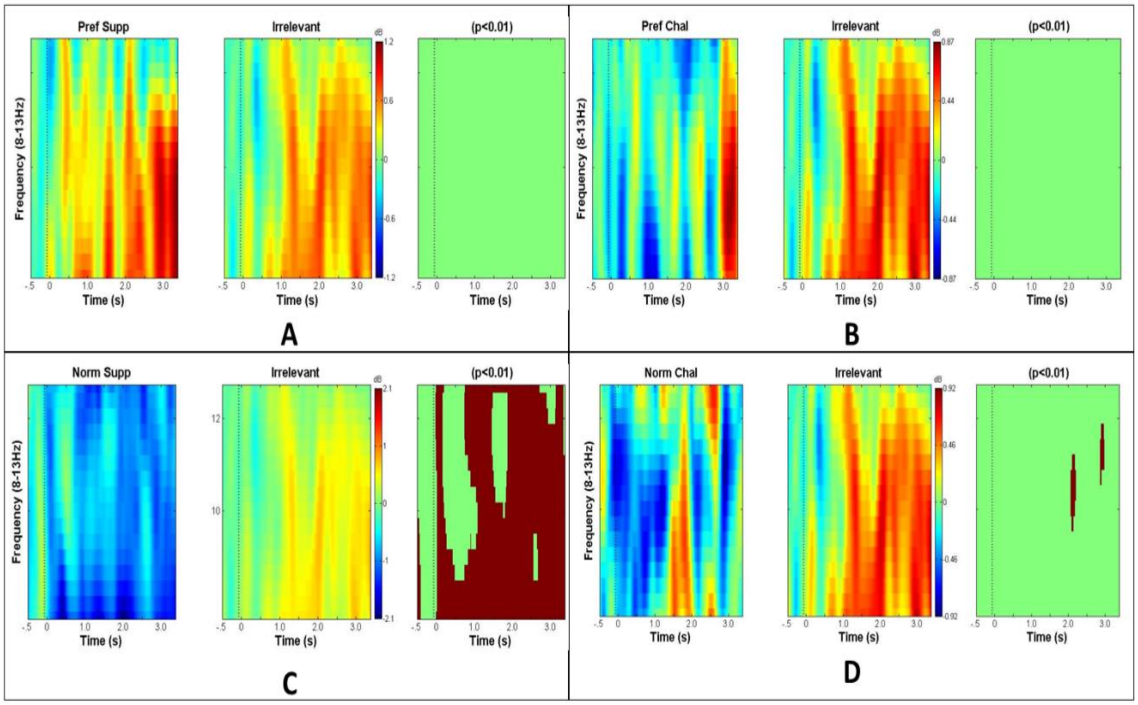

Figure B.5: Example pairwise ERSP comparisons in Minas et al (2014)

APPENDIX C: CONCURRENT PRIMING STIMULI

Examples of the pictures used in the concurrent priming treatment are provided below. The full set of pictures are provided in a supplement to this dissertation. The pictures related to achievement were chosen based on a set of themes. One picture from each set of themes is provided below. These pictures were rated by a set of students and were found to be significantly more related to achievement and have more positive valence and arousal than the neutral images. Thirty images were included in the achievement priming set of images.

FIGURE C.1: Example of "winning in sports" achievement theme

FIGURE C.2: Arms raised in victory achievement theme

FIGURE C.3: Graduation achievement theme

FIGURE C.4: Awards achievement theme

Two examples of neutral images are provided below. A full list of the neutral images is provided in a supplement to this dissertation. Thirty pictures were selected for the neutral priming condition.

FIGURE C.5: Example of neutral image

FIGURE C.6: Example of neutral image

FIGURE C.7 Example of Generic Positive Image

FIGURE C.8 Example of Generic Positive Image

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Zajonc, R. B. 1984."On the primacy of affect," *American Psychologist* (39:2), pp 117-123.

Zajonc, R. B. "Feeling and thinking: Closing the debate over the independence of affect," in: *Feeling and thinking: The role of affect in social cognition*, Cambridge University Press, New York, NY, US, 2000, pp. 31-58.

Zemack-Rugar, Y., Bettman, J. R., and Fitzsimons, G. J. 2007."The effects of nonconsciously priming emotion concepts on behavior," *Journal of Personality and Social Psychology* (93:6), pp 927-939.

RANDALL K. MINAS, JR.

rminas@hawaii.edu

EDUCATION

INDIANA UNIVERSITY, BLOOMINGTON, IN
Ph.D. in Information Systems **2014**
Minor in Cognitive Neuroscience
Dissertation: Designing for the Subconscious: A NeuroIS Study of Priming and Idea Generation
in Electronic Brainstorming, Chair, Alan R. Dennis

INDIANA STATE UNIVERSITY, TERRE HAUTE, IN
Master of Business Administration **2010**
Concentration in Finance

VANDERBILT UNIVERSITY, NASHVILLE, TN
Bachelor of Science in Psychology **2005**
Concentration in Neuroscience

RESEARCH INTERESTS

Information Systems

- Virtual Teams/Collaboration, Healthcare, Decision Making, Individual Cognition, NeuroIS

HONORS, AWARDS AND GRANTS

- Doctoral Consortium at the *International Conference on Information Systems*. Milan, Italy **2013**
- Best Paper in the Collaboration Systems and Technology Track at *45th Hawaii International Conference on System Sciences*, Maui, Hawaii **2012**
- Outstanding Graduate Assistant Award, *Indiana State University,* Terre Haute, IN **2010**
- Graduate Student Research Grant, *Indiana State University*, Terre Haute, IN **2010**
- Honors Society of Phi Kappa Phi, *Indiana State University*, Terre Haute, IN **2010**
- McDonald Award for exerting the greatest influence on campus cultural life, *Culver Academies*, Culver, IN **2001**

PUBLICATIONS

Dennis, A.R., Bhagwatwar, A., & Minas, R.K. (Conditional Acceptance). Play for performance: Using computer word games to improve test-taking performance. *Journal of Information Systems Education.*

Minas, R.K., Potter, R.F., Dennis, A.R., Bartelt, V., & Bae, S. (2014). Putting on the thinking cap: Using NeuroIS to understand information processing in virtual teams. *Journal of Management Information Systems* 30(4), 49-82.

Massey, A.P., Khatri, V., & Minas, R.K. (2013). The influence of psychographic beliefs on website usability requirements. *AIS Transactions on Human-Computer Interaction* 5(4), 157-174.

Dennis, A.R., Minas, R.K., & Bhagwatwar, A. (2013). Sparking creativity: Improving electronic brainstorming with individual cognitive priming, *Journal of Management Information Systems* 29(4), 195-216.

Minas, R.K., & Park, S. (2007). Attentional window in schizophrenia and schizotypal personality: Insight from negative priming studies. *Journal of Applied and Preventive Psychology* 12(3), 140-148.

ARTICLES UNDER REVIEW AND IN PROGRESS

Lockwood, N.S., Dennis, A.R., & Minas, R.K. (Second Round Review). Mapping the corporate blogosphere: Linking audience and content to blog success. *Journal of AIS.*

Minas, R.K., Yuan, L., Khatri, V., & Samuel, B. (In Progress, Writing). Identifying heuristics during SQL debugging using eyetracking. Target *MIS Quarterly***.**

Minas, R.K., Dennis, A.R., & Massey, A.P. (In Progress, Writing). Open up your thinking: Increasing idea generation in 3-D virtual worlds with a prime integrated into the environment. Target *Information Systems Research*.

Minas, R.K. & Dennis, A.R. (In Progress, Writing). Increasing individual brainstorming with priming. Target *Journal of Applied Psychology*

Dennis, A.R., Poor, M., & Minas, R.K. (In Progress, Initial Data Collected). The effects of a supraliminal priming computer game on food restriction and dieting.

Dennis, A.R., Warkentin, M., Johnston, A., Minas, R.K., & Menard, P. (In Progress, Concept Developed). Priming security related concepts, elaboration likelihood model, and cognition: An EEG Study. Target *MIS Quarterly*.

Dennis, A.R. & Minas, R.K. (In Progress, Conceptual Development). Creating design principles for developing systems directed at enhancing the user's subconscious processes. Target *MIS Quarterly*.

CONFERENCE PROCEEDINGS AND ABSTRACTS

Minas, R.K., Potter, R.F., Dennis, A.R., Bartelt, V., & Bae, S. (2013). Overloaded or biased? Using EEG and NeuroIS to elucidate information processing in virtual teams. *3rd Annual Interdisciplinary Symposium on Decision Neuroscience. Philadelphia, Pennsylvania.*

Dennis, A.R., Minas, R.K., & Bhagwatwar, A. (2012). Sparking creativity: Improving group brainstorming with a supraliminal priming computer game. *45th Hawaiian International Conference on System Sciences. Maui, Hawaii.* ****Best Paper Award in the Collaboration Systems and Technology Track at HICSS 45***

Minas, R.K., Yuan, L., & Khatri, V. (2012). Top-down, bottom-up or just information foraging? Exploring the process of corrective SQL maintenance tasks. *11th Annual Symposium on Research in Systems Analysis and Design. Vancouver, Canada.*

Dennis, A.R., Bhagwatwar, A., & Minas, R.K. (2012). Play for performance: Using computer word games to improve test-taking performance. *45th Hawaiian International Conference on System Sciences. Maui, Hawaii.*

Dennis, A.R., Minas, R.K., & Bhagwatwar, A. (2011). Sparking creativity: Improving group brainstorming with a supraliminal priming computer game. *Big 10 Information Systems Conference. Cleveland, OH.*

Minas, R.K. & Harper, J. (2010). Adoption and use of information technology by healthcare practitioners. *14th Annual Conference on Education. Athens, Greece.*

Minas, R.K., Cowan, R.L., & Park, S. (2008). Increased schizotypal traits and altered affect in young cannabis users. *The College on Problems of Drug Dependence. San Juan, Puerto Rico.*

Minas, R.K. & Park, S. (2007). Increased psychoticism and reduced negative affect in young cannabis users. *Proceedings of the 11th International Congress on Schizophrenia Research. Colorado Springs, CO.*

RESEARCH EXPERIENCE

INDIANA UNIVERSITY, BLOOMINGTON, IN
Research Assistant **2010 – Present**

- Conducted research with Alan Dennis on the intersection of information systems and cognition
- Administered study for Vijay Khatri on elicitation of usability requirements by systems analysts
- Analyzed data in SPSS, SAS, MATLAB, LISREL, and M-Plus for various research projects
- Completed literature review on usability for Anne Massey and Vijay Khatri
- Completed data collection on projects involving EBS, SQL Correction, and Virtual Worlds in behavioral laboratory

INDIANA STATE UNIVERSITY, TERRE HAUTE, IN
Graduate Assistant **2009 – 2010**

- Completed a literature review of healthcare informatics under the supervision of Jeffrey Harper in order to launch a research project examining the implementation and adoption of healthcare information systems in various healthcare settings in the United States
- Collaborated with Jeffrey Harper and Jeff Edwards to determine the feasibility of a Healthcare Informatics Program at Indiana State University

VANDERBILT UNIVERSITY, NASHVILLE, TN
Research Analyst **2004 – 2008**

- Conducted research in the Clinical Neuroscience Laboratory under the supervision of Sohee Park, Ph.D., to examine the effects of cannabis use on memory, attention, personality, and creativity using a National Institute on Drug Abuse grant
- Analyzed imaging data including fMRI, Near Infrared Optical Tomography, and PET using BrainVoyager
- Analyzed cognitive data including; negative priming, working memory, and biological motion in SPSS
- Created a multi-functional, relational database in FileMaker Pro 8.0 to streamline operations within the laboratory

- Managed day-to-day operations in the laboratory and assisted in directing undergraduate researchers
- Completed two hundred hours of clinical interviews for cannabis users, patients with schizophrenia, and patients with bipolar disorder to include:
    - Intelligence estimation using the Wechsler Abbreviated Scale of Intelligence
    - Symptoms ratings using the Brief Psychiatric Rating Scale, Social Functioning Scale, Scale for the Assessment of Positive Symptoms, and Scale for Assessment of Negative Symptoms

RELATED EXPERIENCE

MIS QUARTERLY EXECUTIVE

Managing Editor
2011 – Present

- Managed day-to-day operations of *MIS Quarterly Executive* under the direction of Editor-in-Chief Carol V. Brown and Publisher Alan R. Dennis
- Managed the production cycle for quarterly issues of the journal, including typesetting articles,
  editing cycle, printing press and mailings, author correspondence, and interactions with Society for Information Management
- Coordinated with Senior Editors and Editorial Board during review process
- Managed subscriptions, purchases, and website
- Created a new article layout under the direction of the Publisher and Editor-in-Chief
- Served as coordinator for Pre-ICIS Academic Workshop
- Attended *MIS Quarterly Executive* board meetings

TEACHING EXPERIENCE

INDIANA UNIVERSITY, BLOOMINGTON, IN

Associate Instructor
Courses Taught

- BUS-S 400 Integration of Systems and the Business/Accounting Information Systems **Spring 2013**
    - Teaching Evaluations: Mean, 5.73/7 Median, 5.88/7
- BUS-K 201 The Computer in Business **Spring 2014**

Graduate Assistant

- BUS-G 202 Business, Government, and Society **Fall 2012 – Spring 2014**

SERVICE

INDIANA UNIVERSITY, BLOOMINGTON, IN

Co-Chair for the Doctoral Student Association **2011 – 2014**
Doctoral Student Representative for Kelley School of Business Dean Search Committee **2013**
Business School Representative for the Indiana University Graduate and Professional Organization **2013**

INDIANA STATE UNIVERSITY, TERRE HAUTE, IN
Executive Committee, President's Council on Diversity **2008 – 2010**
Graduate Student Representative, Student Success Council **2009 – 2010**

- Council to determine how to strategically increase student retention by ensuring academic success
  and integration into Indiana State University

VANDERBILT UNIVERSITY, NASHVILLE, TN
Co-Chair of Stepping Out Support Group **2005 – 2008**

- Created and facilitated a support group for individuals struggling with sexual orientation and gender identity

Opinion Columnist for the Vanderbilt student newspaper the *Vanderbilt Hustler* **2005**

REVIEWING ACTIVITIES

MIS Quarterly
Journal of Management Information Systems
Journal of AIS
International Journal of Electronic Commerce
International Conference on Information Systems
Hawaii International Conference on System Sciences
Americas Conference on Information Systems
Pacific Asia Conference on Information Systems

PROFESSIONAL EXPERIENCE

Foundation Relations Coordinator, *Indiana State University Foundation, Terre Haute, IN* **2008 – 2009**

- Served as Junior Executive for Sycamore Foundation Holdings, LLC, a newly chartered subsidiary of the Indiana State University Foundation
  - Evaluated feasibility of real estate opportunities in Terre Haute, IN
  - Organized Executive Board meetings
  - Managed financial statements
- Attended Investment Committee meetings
  - Reviewed meeting agendas and organized financial statements for Indiana State University Foundation's $39 million endowment
  - Reviewed and executed the Investment Committee's investment decisions under the supervision of Kevin Hoolehan, Vice President of Finance and Operations
  - Assisted in the creation of a new Investment Policy
- Assisted in managing the Operations Department
  - Completed budget projections for 2009-2010 Fiscal Year

Lab Manager, Clinical Neuroscience Laboratory, *Vanderbilt University, Nashville, TN* **2005 - 2008**

- Managed day-to-day operations in the laboratory, scheduled subjects, and assisted in directing undergraduate researchers
- Created a multi-functional, relational database in FileMaker Pro 8.0 to streamline operations within the laboratory

General Office Assistant, *Merrill Lynch, Merrillville, IN* **2001 – 2002**

- General Office Assistant for Shawn Sabau in the Minas, Sabau, Haas Investment Group

FORMAL EDUCATIONAL PRESENTATIONS AND WORKSHOPS

MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY, ROLLA, MO

- Lectured and conducted workshop titled "Applying neuroscience to the information sciences: A NeuroIS overview" for the faculty and students of the Business and Information Technology Department **2013**

MISSISSIPPI STATE UNIVERSITY, STARKVILLE, MS

- Ran workshop for Merrill Warkentin on using electroencephalography **2013**

(EEG) for the doctoral students in the MIS Department

INDIANA STATE UNIVERSITY, TERRE HAUTE, IN

- Lectured on diversity titled “Hate Crimes In America” for Political Science course instructed by Carl Klarner **2009**

VANDERBILT UNIVERSITY, NASHVILLE, TN

- Lectured on diversity titled “Heart of the Matter” to Vanderbilt’s LAMBDA Organization **2006**
- Panelist for “The Untold Story” Discussion of LGBT life at Vanderbilt University **2005**

OASIS CENTER, NASHVILLE, TN

- Lectured at various high schools and organizations in Nashville, TN on cultivating diversity and inclusiveness **2004 – 2005**

COMMUNITY SERVICE

- Hurricane Katrina Relief Trip **2005**
  - Assisted in relief efforts in Washington Parish, LA in October, 2005
- Quad Town Safety Village
  - Fundraised for a project focused on teaching youth safety information about drugs, fires, guns, and other hazards **1999 – 2007**