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FUNNY BRAIN ACTIVITY: AN ERP ANALYSIS OF INSIGHT

by

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Achieving a clear and sudden solution following a task is an experience that people sometimes reach after being stuck in a problem-solving situation. This experience is known as insight or the A-ha! moment. Because of its distinctiveness, insight has received significant scientific attention. However, problems within the methods and paradigms used to study insight have kept the underlying mechanisms mysterious. This paper offers a new direction in the study of insight using electroencephalograms (EEGs) and event-related potentials (ERPs). The following study used jokes to elicit passive insight in participants.

The study recruited 40 participants to view and rate 20 jokes and 20 nonjokes, while having their electrophysiological activity recorded using an EEG. A multivariate within subject design with one independent variable (IV) of two conditions was implemented. The experimental condition was made up of funny and surprising strips. The control condition was made up of strips that were neither funny nor surprising. The control strips were altered versions of the experimental strips, the humorous aspect being modified into a neutral and coherent aspect.

The results of our study suggest that the prefrontal cortex is not linked to insight, but rather to the attention, awareness, and level of difficulty required to complete certain tasks. It also confirmed the role of the anterior cingulate cortex. The N300-500 reflects the cognitive conflict or surprise that results from a break in the mental impasse. The P1500-2000 reflects incongruence resolution, which is thought to be the same as formation of new associations. There is no activation of the superior temporal gyrus in the early stages of insight (200-600ms). However, a left-brain lateralization in the STG appears (600-2500ms). This is speculated to be the result of the type of task being carried. Humor appreciation is seen in the anterior cingulate cortex as P2000-2500. Limitations of this study and recommendations for future research are discussed.

Keywords: Insight, ERP, EEG, Humor, superior temporal gyrus, anterior cingulate cortex, prefrontal cortex.

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CHAPTER I

OVERVIEW OF INSIGHT

A. Introduction

Almost everyone has had an insightful experience at one point in life. Most of these situations count as minor events, such as suddenly finding a solution to a math problem, understanding a riddle, and so on. However, many stories exist throughout history about moments of insight that revolutionized the world. Archimedes' buoyancy principle, Mendeleev's periodic table, Kekule's benzene structure, and Newton's law of gravitational force were all discoveries that originated from an insight moment. Whether it be historical discoveries, artistic creations, or personal revelations, a sudden flash of insight can be a profound experience.

Researchers from various schools have explored the nature and consequences of insight. This thesis focuses on the neuroscientific nature of insight, specifically examining the ERP components that are related to insight. Insight, in this study, is explored by using jokes as stimuli. While many ERP components have been associated with insight, this study attempts to discern those components that are directly implicated in insight from those that are due to extraneous variables, such as language, difficulty of a task, the type of task, etc.

In this thesis, we first define and outline research on insight, EEG's, humor, and the use of jokes in the study of insight. Subsequently, the aims of the present research as well as the methods used to undertake the study are detailed. We then present the statistical analysis conducted and the results. Finally, the implications of the results, and the limitations of the study are detailed in the discussion section.

B. What is Insight?

Insight is a sudden understanding that results in a new analysis of a situation or problem. It is often considered the opposite of analytical problem solving because it entails the sudden emergence of an unexpected solution into consciousness. It is referred to in the field as the "A-ha! experience" (Sternberg & Davidson, 1995). For insight to occur, a person must first be presented with a problem. Then, while searching for an answer to the problem, people hit an impasse (Bowden, Jung-Beeman, Fleck, & Kounios, 2005). This impasse is due to constraints about how the problem should be solved, usually set by the person him/herself. Whether they are on a conscious level or not, these self-imposed constraints prevent all progress on the problem. An integral component of insight is the relaxation of these very constraints, which leads the person to persist on the incorrect path (Knoblich, Ohlsson, Haider, & Rhenius, 1999). It is only when a relaxation of the constraints occurs that the person is able to reinterpret the problem in the way that makes it solvable. This reinterpretation might then lead to an insight solution (Dietrich & Kanso, 2010). If so, individuals experience an ease in processing the problem that includes an increase in positive affect as well as feelings of gratification and confidence (Topolinski & Reber, 2010). There are two ways in which insight can be gained: active and passive insight. Active insight, or internally triggered insight, is one in which the problem solvers achieve insight on their own. The other is passive insight, or externally triggered insight, which occurs when a hint or even the solution itself is given to problem solvers and they simply understand it (Luo & Knoblich, 2007).

While insight is linked to various cognitive processes, its strongest link remains with creative problem solving. Both insight and creativity rely on novel combinations of information. The insight process described above can be a vital part of creativity. Insight remains one possible, although not always necessary, component of creativity. Creative solutions are characterized by three features: novelty, appropriateness of a potential solution, and surprise (Simonton, 2012). The novel combination of information that suddenly and surprisingly appears in one's mind needs to be an appropriate solution to the problem. The appropriateness of the solution is a critical component. Without appropriateness as a key factor, for example, the often novel but bizarre thoughts of people with schizophrenia would be considered creative. In most instances of creativity, it is insight that triggers the process resulting in a creative solution (Dietrich & Kanso, 2010).

Experimental work on creativity and insight was first pursued by Gestalt psychologists in the mid-1900's (Dietrich & Kanso, 2010). The term "insight" was coined by Gestaltists to refer to the A-ha experience. Following Thorndike's research, the prevailing view was that animals learned through trial-and-error. Kohler challenged Thorndike's conclusion and attempted to show that animals can reach a solution through insight, not trial-and-error. Most of his research was on chimpanzees that had to reach for food. In these studies, the only way that they could reach the food was by being creative. The chimpanzees were able to reach insightful solutions on their own after contemplation (Kohler, 1924). Based on his research, Kohler attributed three properties to insight learning. First, the animal has to perceive the solution. Second, unlike Thorndike's theory, insight learning is not dependent on rewards. Third, it becomes easier to solve a problem after similar problems have been solved (Hothersall, 1995). After Kohler's research on insight, the study of insight and its underlying mechanisms dwindled. It was not until the beginning of the 21st century that researchers began to examine the neural mechanisms of insight. Neuroscientists have tackled this subject using tools such as electroencephalograms (EEGs), event-related potentials (ERPs), positron emission topography (PET), and functional magnetic resonance imaging (fMRI) (Xing, Zhang, & Zhang, 2012). Various EEG and ERP studies have been conducted in an attempt to understand the underlying neural mechanisms. However, because of the variability in the testing tools and experimental paradigms, results are highly discrepant (Dietrich & Kanso, 2010).

C. Paradigms Used to Study Insight

The main kerfuffle behind the discrepancies in the results of insight studies lies in the difference between the methodologies and designs of these studies. The field has relied on tasks that differ in structure, complexity, and required cognitive resources. Traditional insight problems, such as Duncker's Candle Problem and the Two-String Problem, have been used in some insight research (e.g., Lavric, Forstmweier, & Rippon, 2000). In Duncker's Candle Problem, a person is asked to fix a lit candle on a wall, using a box of pins, in such a way that wax does not drip onto the floor. Similar in structure, the Two-String Problem requires the participant to find a way to hold two strings hanging from the ceiling using a chair and a pair of pliers. These strings are normally unreachable at the same time. Such paradigms were made to study functional fixedness. However, the tasks were also used to study insight because it was stipulated that the only way to solve them is through achieving insight. The use of such tasks was prominent in the early days of insight studies, mainly because they offered a concrete definition for the solution of insight tasks. The similarity of tasks used and lack of variation ensured that the study of insight was more or less standardized. To study insight, participants were given a variety of traditional insight tasks to perform. However, their use does not go without limitations. To begin with, the intricate level of the tasks makes it difficult to obtain a large number of participants who achieve the insight. The small number of insight tasks also limits the variety of techniques as well as the reliability of data. Moreover, it requires an extended amount of time to potentially solve the task (Bowden et al., 2005; Haider & Rose, 2007). Additionally, classic insight problems were not always found to yield an insightful solution. Such problems can become less insight-like after a few trials, as the participants sometimes learn the strategy needed to solve this type of task (Subramaniam, 2008).

Due to the problems related to traditional insight tasks, the bulk of tasks used in insight research has been language-related tasks. Such tasks range from semantic grouping of different words into one category (Bechtereva et al., 2004; Danko, Starchenko, & Bechtereva, 2003; Starchenko, Bekhtereva, Pakhomov, & Medvedev, 2003), anagrams (Aziz-Zadeh, Kaplan, & Iacoboni, 2008; Kounios et al., 2008) to riddles using ambiguous sentences or words with double-meanings and Chinese logogriphs (Luo & Niki, 2003; Luo, Niki, & Philips, 2004; Mai, Luo, Wu, & Luo, 2004; Qiu, Luo, Wu, & Zhang, 2006a; Qiu et al., 2008a; Qiu et al., 2008b; Shen et al., 2013; Shen, Liu, Zhang, & Chen, 2011). Other language-related problems are compound remote associates (CRA) tasks, in which the person is asked to find a word that can form a compound word with all the other given words (Jung-Beeman et al., 2004; Kounios et al., 2006; Sandkühler & Bhattacharya, 2008).

Language tasks were created to bypass problems that were associated with classic insight tasks. CRA tasks, anagrams, and word grouping were fashioned as a replacement for classic insight tasks. The rationale behind their formation was that these tasks depend on the same component processes involved in classic insight tasks, such as an initial misdirection in solution efforts, an inability to explain how one overcame the impasse, etc. (Bowden et al., 2005). Chinese logogriphs followed the same logic for their creation as the western verbal tasks. However, Chinese logogriphs count on adding/omitting components of the characters to create an entirely new meaning, and are therefore a better choice for Chinese participants (Qiu et al., 2006b). Verbal tasks have several advantages over classic insight tasks. First, it makes it easy for experimenters to develop new items. Second, as opposed to traditional insight problems, language-related problems require a short amount of time to achieve the solution. Third, this method is argued to specifically distinguish insight from conscious algorithmic solutions, as participants report when they have solved the task using insight (Bowden et al., 2005). These factors have contributed to an increased use of language related tasks in the study of insight. However, the main confound with these tasks is the verbal component. Because the majority of the insight problems are verbal, it is unclear in the literature which parts of the results are related to the linguistic nature of the paradigm and which parts are related to insight.

A new method has recently been used to avoid relying on self-report of insight instances. Jarman (2014) created two scales. The first measures the degree of deviation between the final solution and initial solution attempts. The second scale measures how participants felt once restructuring of the problem has occurred. These two measurements allow to quantify insight and pinpoint when it occurs. Jarman argues that this provides a natural setting in which to study insight. It also gives a more precise characterization of the insight experience. However, the scales cannot be generalized to other types of stimuli, as they currently stand. Rather, they remain bound to this specific set of stimuli. Furthermore, this method still heavily relies on language in the type of stimuli it uses.

To bypass the language problem altogether, Haider and Rose (2007) propose the use of implicit learning tasks, such as the Number Reduction Task (NRT) and the Serial Reaction Time Task (SRTT), to study insight. The NRT and SRTT were initially used to study implicit learning. It was by accident that the researchers realized that some participants did not use the normal method to solve the task, but rather solved it through insight (Haider & Rose, 2007). Such tasks have an underlying regularity that makes them much easier and faster to solve. While this regularity is not mentioned to participants, some participants, nonetheless, develop insight into this consistency while going from trial to trial. These participants can also explicitly explain the regularity once the experiment is completed (Lang et al., 2006; Rose, Haider, & Büchel, 2005; Rose, Haider, Weiller, & Büchel, 2002).

These methods allow researchers to study insight on a trial-by-trial basis within a short period. Another advantage is that the problems are relatively easy and language-free. Unlike other studies that rely on verbal reporting of insight occurrences, the main strength of this technique is the ability to pinpoint insight by looking at time reduction, not verbal report. Nevertheless, this method is not without shortcomings either. Participants who develop insight do so throughout a series of steps. They first suspect the presence of a regularity. They then need to test this regularity as a possible solution. Participants do so over a period of several trials. Thus, it takes them a prolonged time to discover the entire sequence. Since the process of insight, in this case, takes a prolonged duration of time, it makes it difficult for researchers to pinpoint brain functioning during insight (Haider & Rose, 2007).

D. Electroencephalogram (EEG) and Event-Related Potential (ERP) Findings

Different brain activities have been linked to the phenomenon of insight. Up to this date, there are no consistent findings with regards to insight. Inconsistencies in brain activity exist among all neuroscientific insight-related studies. The roles of the prefrontal cortex, anterior cingulate cortex, and superior temporal gyrus are still in dispute. The variances in the testing tools have resulted in a considerable amount of variability when comparing brain activity across studies. Moreover, the variances have led to a controversial and highly isolated right-brain theory of insight (Dietrich & Kanso, 2010). The different brain activities and their implications are discussed below.

While most findings are inconsistent from study to study, a change in alpha power in frontal, parietal, and temporal regions is found more consistently in the available research. However, the direction of this change remains highly incongruous (Dietrich & Kanso, 2010). For all the measures regarding insight, there is an inconsistency. Different frequency bands are also associated with insight. For instance, some researchers found general gamma and beta power increases to be correlated with insight (Kounios et al., 2008; Sandkühler & Bhattacharya, 2008). Researchers interpreted the gamma and beta power increases as an adjustment of selective attention. These findings, however, were not replicated in other studies. One study showed a general decrease in all frequency bands, particularly in the frontal cortex (Danko et al., 2003). This finding was also not replicated in any other study. As such, the role of prefrontal areas remains unclear due to disparities between the results from EEG/ERP and from fMRI studies. For instance, some EEG data show alpha power decreases during insight. fMRI studies should have replicated these findings by showing a decrease in blood oxygenation levels in the prefrontal cortex. Such a correlation has not been found (Dietrich & Kanso, 2010). One explanation is that prefrontal activity is only related to the difficulty of the problem rather than to the insight itself. Difficult analytical solutions have been shown to activate the prefrontal areas to the same extent as insight. This might be because a difficult problem requires more attention. The increase in attention would explain the increase in prefrontal cortex activity (Luo et al., 2004).

The A-ha! moment has also been associated with an activation in the anterior cingulate cortex (ACC), as shown by many ERP studies (Mai et al., 2004; Qiu et al., 2006a; Qiu et al., 2008a; Xing et al., 2012; Zhang, Tian, Wu, Liao, & Qiu, 2011). The ACC appears to be associated with triggering the processes of breaking the purportedly erroneous initial thought process. While most researchers agree that the ACC is activated during insight, findings have been split concerning the polarity of the deflection and latency associated with that activity (Dietrich & Kanso, 2010). Negative deflections have been observed at N320 (Qiu et al., 2006a), N380 (Mai et al., 2004; Shen et al., 2011), N300-500 (Xing et al., 2012), and N320-500 (Shen et al., 2013) which have been hypothesized to reflect the cognitive conflict that results from breaking the mental impasse. Other negative deflections, such as N1500-2000 (Qiu et al., 2008b), have been implicated in the formation of novel associations after the impasse break. On the other hand, Qiu et al. (2006b), Xing et al. (2012), and Zhang et al. (2011), have reported positive deflections at P500, P730, and P600-1100, which were also interpreted as the formation of novel associations. The difference in findings is peculiar, especially since both negative and positive deflections in the ACC are associated with the formation of novel associations. These differences might be due to the characteristics of the different insight problems. The various characteristics include the problems' complexity, difficulty, and overall variability (Dietrich & Kanso, 2010).

This variability has also contributed to another problem. The verbal component in the insight studies that use language-related tasks has shown lateralization. This led some researchers to attribute a right-brain theory of insight. Such studies (Jung-Beeman et al., 2004; Kounios et al., 2008; Qiu et al., 2006a; Sandkühler & Bhattacharya, 2008; Shen et al., 2011; Shen et al., 2013; Zhang et al., 2011) have implicated the superior temporal gyrus (STG) in facilitating the formation of remote associations. However, these are isolated cases of lateralization findings. There is a greater number of studies that do not support this lateralization (Danko et al., 2003; Kounios et al., 2006; Lang et al., 2006; Lavric et al., 2000; Mai et al., 2004; Qiu et al., 2008a, 2008b). One study (Qiu et al., 2008a) even contradicts this finding by giving the left hemisphere the role of forming remote associations. The majority of researchers in the field agree that Aha-moments are not generally accompanied by right-hemispheric dominance (Dietrich & Kanso, 2010). Again, the problem behind the role of STG lies in language. Insight tasks in which STG was associated were all verbal. Insight, consequently, is posited to be integrated within semantic coding (Kounios & Beeman, 2014). This means that insight would have to show a hemispheric asymmetry regardless of the nature of the stimulus, which is not the case. Non-language tasks did not show any activation of the STG. Therefore, it has been posited that the STG plays a role in forming remote verbal associations. The hemispheric difference, in this case, pertains to the verbal component of the problem, and not to the lateralized nature of insight (Dietrich & Kanso, 2010). It is not insight that is lateralized, but rather the verbal components associated with these insight problems.

This study explored these different components during insight. Classic problem solving methods are limited by their difficulty, limited number, and the time required for a potential solution (Bowden et al., 2005; Haider & Rose, 2007). Language-related insight problems, on the other hand, are limited by the inability to separate results arising from the semantic nature of the problem and those pertaining to insight itself (Dietrich & Kanso, 2010). The lack of a constricted time-frame for insight in implicit learning tasks makes their use limited as well. For these reasons, a new method of studying insight was proposed here. Insight was presented using paraprosdokians.

CHAPTER II

OVERVIEW OF HUMOR

Humor is an interesting and unique aspect of human behavior (Nahemow, McCluskey-Fawcett, & McGhee, 1986). It plays an important role in social interaction and can also be a significant coping strategy (Du et al., 2013). Humor is a main focus of positive psychology. It is studied as a factor in character building, resilience, self-efficacy, and coping (Fredrickson, 1998). Alleviation of distress using humor has shown immediate positive results (Strick, Holland, Van Baaren, & Van Krippenberg, 2009). It can also restore autonomic quiescence after negative affect (Fredrickson & Levenson, 1998). Exposing people to humor regularly was also found to increase their self-esteem, decrease levels of depression, anxiety, and perceived stress (Abel, 2002). It also correlates with ameliorating physical health in people with certain diseases, such as heart conditions, asthma, as well as surgery recovery (Solomon, 1996). Research on humor is also important to understand why humor sometimes fails to deliver. Failed attempts of humor can be destructive to a person's self-esteem and social interactions. It can also be destructive to industries, as is the case with marketing mistakes (McGraw & Warner, 2014). The study of humor can contribute to enhancing mental health as well as physical recovery, and when used correctly, can boost companies' finances and public relations.

Humor has, for the most part, been studied through the use of jokes. It was posited that jokes break down into two elements: cognitive and affective (Gardner, Ling, Flamm, & Silverman, 1975). The cognitive element appears when the person tries to understand the incongruences between the punchline and the first part of a joke (Brownell, Michel, Powelson, & Gardner, 1983). The affective element, on the other hand, is when the person experiences an emotional response brought about by the joke (Moran, Wig, Adams, Janata, & Kelly, 2004).

People process humor through different components (Coulson & Kutas, 2001). The cognitive aspect can be divided into two components: the detection of incongruity and its resolution, as proposed by Suls (1972) in the "Incongruence-Resolution Theory." Double dissociation studies have shown a dissociation between the cognitive and the affective elements of a joke, as well as between the incongruity detection and resolution stages (Brownell et al., 1983; Gardner et al., 1975; Wapner, Hamby, & Gardner, 1981). These studies found a set of steps involved in the understanding of a joke. In the first part of the joke, the person is led to believe that the joke is going in one direction. The second part of the joke then comes as a surprise, as it has a different meaning than originally believed (Yamaguchi, 1988). For these jokes to be successful, the first part must have a context C_1 that leads the recipient to assume a hypothesis H_1. The joke must be covertly ambiguous. All alternative hypotheses or meanings of words are disregarded because of the context C_1 that has been assumed. The second part of the joke, or the punchline, invalidates H_1 because of a new context C_2 that the second part evokes. The person therefore needs to backtrack and reprocess the initial part of the text to find an alternative meaning, which leads to the second hypothesis H_2 (Jodlowiec, 1991). The process whereby backtracking and reprocessing is possible has been labeled frame-shifting: existing information is reorganized into a new frame retrieved from long-term memory (Coulson & Kutas, 2001; Dynel, 2012).

Studies involving brain imaging techniques on brain asymmetry and joke comprehension have looked at the unexpectedness or surprise of a pun and its correlation with brain activity (Moran et al., 2004). As postulated, a dissociation between the cognitive and affective elements of a joke was found, in which the cognitive aspect is linked to an activity in the posterior middle temporal gyrus and posterior temporal cortices, while the affective element is related to activity in the ventromedial prefrontal cortex, the insular cortex, and the amygdala (Goel & Dolan, 2001; Moran et al., 2004). Several studies have shown an important ERP depolarization N300-500 after the presentation of the punchline (Coulson & Severens, 2007; Coulson & Kutas, 2001; Coulson & Williams, 2005; Derks, Gillikon, Bartolome, & Bogart, 1997). In fMRI studies, temporal and left frontal areas were associated with humor (Goel & Dolan, 2001; Ozawa et al., 2000). Amir, Biederman, Wang, and Xu (2013) further associated the medial prefrontal cortex, temporo-occipital junctions, and temporoparietal junctions with the humorous aspect of jokes. These areas were found to be implicated in humor but not insight. This was possible to discern as brain activity from funny insightful solutions was compared with brain activity from unfunny insightful solution. Unfunny insightful solutions did not elicit an activation of these areas.

CHAPTER III

STUDIES ON INSIGHT USING JOKES

In this chapter, I provide an overview of the rather scarce research that exists combining insight and jokes. All of the presented studies have used neuroimaging techniques.

The study of humor using neuroimaging techniques can be tricky, as many confounds can cause different brain activities (e.g., sexual titillation, superiority, attribution of intentions, etc.) (Hurley, Dennett, & Adams, 2011). Research focusing on humor comprehension has tangentially targeted insight. In most jokes, there is a definitive moment when the person understands the joke. This moment relates to the insight experience. In jokes, just like in insight, there is first a reinterpretation of the joke which leads to the understanding. The recipient of the joke usually experiences positive affect and a sense of gratification (Jodlowiec, 1991). Jokes present a form of passive insight, in which the pun is provided to the person. The similarity between jokes and common insight tasks have led some researchers to use jokes to study insight. An additional plus to the use of jokes is that researchers can clearly know when the subject understands a joke, and when they do not. Simply put, people who do not get the joke would not find it funny.

Such studies have found increased activities in the bilateral ventral striatum and left amygdala, two regions associated with reward (Amir et al., 2013; Bartolo, Benuzzi, Nocetti, Baraldi, & Nichelli, 2006). Unsurprisingly, regions responsible for language processing were also activated, such as the right posterior inferior frontal gyrus and Broca's area. More importantly, the ACC was also activated by both humorous and non-humorous surprising stimuli, indicating that insight could be responsible for an activation in the ACC (Amir et al., 2013). The medial prefrontal cortex was only activated by humorous stimuli, which suggests that a prefrontal cortex activation is due to the nature of the stimulus rather than insight. Tu, Ma, Zhao, Zhang, and Qiu (2014a), on the other hand, focused their fMRI study on incongruity detection in humorous stimuli. Important activations in the amygdala and insula were found. It was suggested that the insula and the amygdala are involved in detecting incongruities in cartoons. fMRI studies provide great information concerning the differentiation between cognitive and affective elements of joke comprehension. However, their low temporal resolution make it difficult to study the differentiation between incongruence detection and resolution (Du et al., 2013).

Studies concerning the differentiation of this incongruence have primarily used EEGs/ERPs. The surprise in the joke is reflected in the negative deflection N400 in the temporal gyrus and medial frontal gyrus (Coulson & Williams, 2005; Coulson & Severens, 2007; Coulson & Lovett, 2004). The resolution of the incongruity, on the other hand, was found to be linked to a positive deflection P600-800 in the anterior cingulate cortex (ACC) (Du et al., 2013). A third stage in humor processing was also postulated by Du et al. (2013), in which a positive ERP deflection P1250-1400 is thought to be linked to humor appreciation. Tu et al. (2014b) further divided the incongruence resolution timeframe results into association evaluation and incongruity resolution. Association evaluation is thought to be linked to a positive ERP deflection P800-1000 and incongruity resolution to a positive deflection P1000-1600. They also associated humor appreciation to a positive deflection P2000-2500. While attempting to study the same mechanisms, these studies showed inconsistencies in the timeframe of ERP deflections. Such differences can be due to the different types of stimuli used in each study: word jokes, episodes of TV sitcoms, laughter, etc. The time it takes for participants to figure out a joke varies depending on the type of stimuli used. This could explain the variances in the existing timeframes of ERP deflections. Another problem in these studies is that the punchlines were always verbal. As expected, hemispheric asymmetry in these studies was found. This perpetuates the issue with language.

Jokes were used in the current experiment to study insight, or more precisely passive insight. It was postulated that the comprehension of the unexpected meaning would be achieved through insight. The non-verbal punchline in jokes was a hint that allowed participants to reinterpret the joke. Participants used the punchline to understand the joke and achieve the Aha! moment. Jokes, in this case, were a part of passive insight.

CHAPTER IV

ELECTROENCEPHALOGRAPHY

This chapter describes the theory behind human EEG recordings. A description of EEG physiology is described first, followed by a brief explanation of ERPs, and the advantages and disadvantages of using EEG recordings to study cognition.

Hans Berger (1929) was the first to use an EEG in a study. Though the study aimed to explore telepathy, what he set up was one of the most important tools to measure brain activity. EEG recordings provide a measure of continuous neural activity, in the form of small voltage fluctuations. These fluctuations are picked up at the scalp using electrodes (Nunez & Srinivasan, 2006). Since Berger's initial study, the EEG has been used in research as an important method in neuroscience and clinical research. Despite having its limitations, the EEG method remains a viable method of studying the brain.

A. EEG Physiology

The EEG signal is the result of the activity of neurons in the brain. Because the tissues between the neurons and the scalp are conductors, researchers are able to record this activity from the scalp using electrodes (Cacioppo, Tassinary, & Berntson, 2000).

Electric signals propagate through the neuronal network in two different ways: action potentials and post-synaptic potentials (PSPs). It is postulated that EEG signal shows PSPs, not action potentials (Allison, Wood, & McCarthy, 1986). Active potentials are regenerative all-or-nothing potentials that last 1ms and propagate from the cell body to the axon terminal along the axon. Once at the axon terminal, action potentials trigger the release of neurotransmitters. PSPs, on the other hand, result from the fluctuation of ions across the post-synaptic cell membrane, once neurotransmitters bind to the post-synaptic receptors. These synaptic inputs can either facilitate the firing of an action potential (Excitatory PSPs) or hinder its firing (Inhibitory PSPs). PSPs usually last a longer time (10-100ms) than action potentials (Kandel, Schwartz, & Jessel, 1991). The longer timeframe of PSPs is why researchers believe that EEGs pick up the PSP signal and not the action potential.

An action potential results in positive charges inside the neuron and negative charges on the outside. This creates an extracellular voltage difference along the neuron. The neuron, in this case, is a dipole with a precise voltage and orientation. Since its strength decreases with distance, it is implied that EEG recordings are more attuned to superficial brain areas (Hämäläinen, Hari, Ilmoniemi, Knuutila, & Lounasmaa, 1993). Around tens of millions of neurons need to be active around the same time to produce a potential high enough to be picked up by the sensors on the scalp (Cooper, Winter, Crow, & Walter, 1965). Because a slower time is needed for PSPs, summation of the neurons' activity is possible. Moreover, in order for an EEG to pick up a signal, the cells have to be aligned and facing the same direction. Such features are normally present in cortical pyramidal neurons, which means that EEGs tend to favor post-synaptic potentials coming from cortical pyramidal neurons (Luck, 2005).

B. Event-Related Potentials

Event-related potentials have been used over the past decades to study the different aspects of cognitive processes behind human cognition and behavior. ERPs are voltage fluctuations within a specific timeframe usually related to an event, such as a stimulus or a response (Luck, 2005). The brain activity in each trial is usually too small when comparing it to sources of noise, both neural and external. To bypass this problem, many trials need to be averaged out to show the brain activity of interest. Therefore, an EEG study usually involves many repetitions of the same type of stimulus. When researchers take an average across participants, the waveforms usually appear smaller than per individual. This is due to the fact that each participant can have slightly different latencies, which results in smaller peaks in the average. However, averaging remains necessary for any study (Luck, 2005).

As with any other imaging method, the EEG carries many advantages and disadvantages. One of the greatest disadvantages is that ERPs are correlational. As such, one cannot rule out the possibility that a different process is behind the results. Another disadvantage is that EEGs have very poor spatial resolution (Cacioppo et al., 2000) As such, researchers cannot locate the exact part of the brain responsible for the electric activity. Additionally, several trials are required for an accurate waveform. This creates obstacles for researchers when designing certain types of studies. Though other imaging techniques surpass the EEG in some features, they share some of the same disadvantages.

When it comes to advantages, one of the best features of the EEG is its excellent temporal resolution. The millisecond time scale resolution allows the study of short-lived events that are not likely to be picked up by other imaging techniques. Second, the EEG can be used to investigate processes that happen on a non-conscious level. Third, the EEG is efficient, easy to apply, relatively inexpensive, and more portable than other neuroimaging techniques (Luck, 2005). For this, the EEG remains a reliable method in neuroscience research.

CHAPTER V

AIMS AND HYPOTHESES

The overall aim of the study was to pinpoint neural markers for funniness and for passive insight. It also aimed to help make it possible to identify, through the EEG/ERP results, what might happen in the brain when a person has an A-ha! moment and/or is entertained. The inconsistencies in the literature pushed us to consider a new type of paradigms. Such a paradigm would isolate the ERP results related to insight from those pertaining to the extraneous variables. The use of jokes to study passive insight offered various advantages. First, understanding jokes is easy and requires a short amount of time. This made it possible to increase the number of trials. Thus, greater number of trials could be used as compared to classic insight problems. Second, jokes were presented in the form of comic strips. The control condition was non-insight strips of a similar construction. The pictorial nature of the punchline in the jokes bypassed the problem of language interference. Third, the use of such jokes ensured the triggering of an A-ha! moment. Rated levels of funniness and surprise were used to determine whether the participant experienced the A-ha! moment. With this approach, there was no need to rely on verbal reports to determine insight. Simply, participants who did not understand a joke did not find it funny or surprising. Considering the elicited circumstances, different EEG/ERP components were expected for insight strips. First, paraprosdokians necessitate a relaxation of the self-imposed constraints. The relaxation leads to the revelation of a new perspective about the joke. An activation of the ACC was expected as a result of this process. The passive nature of the insight allowed the differentiation between the various ACC-related ERP components. This study enabled us to discern which of the ERP components (300-500, 600-800, 1500-2000, and 2000-2500) are associated with passive insight. Second, any activation of the prefrontal cortex would be due to the attention required for the task at hand, as well as the consciousness or awareness level of the task. Consequently, the role of the prefrontal areas in insight became clearer in this study. Third, this study helped uncover basic mechanisms underlying the emergence of passive insight. Previous studies have been problematic in combining results pertaining to insight with those pertaining to the nature of the tasks. This study attempted to isolate the concept of insight using jokes and provide a better understanding of its underlying mechanisms. This new way of studying insight circumvented the need to rely on verbal reports to identify the A-ha moment. Unlike implicit learning tasks, this method provided a specific timeframe in which insight occurred.

The study of insight can benefit many fields. Since achieving both passive and active insight follow the same steps (i.e., hitting an impasse, break of the mental impasse, etc.), the study of either would benefit the study of creativity. Understanding the process behind insight formation would also contribute to the study of creativity. Discerning the neural mechanisms behind insight would help unravel the underlying mechanisms of creativity. Academically, this study would help in a better understanding of the factors implicated in memory formation and retrieval (Smith, 1995). It would also assist in uncovering the neural components of creativity (Dietrich & Kanso, 2010). Moreover, it would shed light on the roles of the different brain areas implicated with insight, mainly the prefrontal cortex, the ACC, and the STG. The unraveling of these roles would contribute to the medical treatment of different neurodegenerative diseases, such as those involved with memory, remote associations, and understanding. More directly, understanding the mechanisms behind insight would add to the field of education. An improved grasp of insight learning would lead to the implementation of new ways of learning, methods, and curricula in the classroom. Students would be taught to look at the big picture and understand it before studying parts separately. Since most new ideas, concepts, and discoveries are the result of insightful learning, implementing this form of learning from a young age would enhance their ability to invent and develop on ideas. For this to occur, there has to be a starting point. The starting point, in this thesis, is the studying of insight using jokes.

The following sets of hypotheses are proposed:

Hypothesis 1: Selected jokes will be significantly funnier and more surprising than non-

jokes.

Hypothesis 2: There will be no significant difference in activity in the prefrontal cortex between jokes and non-jokes, since attention and a level of consciousness towards the stimulus are required to complete the task, regardless of whether it is a joke or a non-joke.

Hypothesis 3: Significant differences in activity in the frontocentral anterior cingulate cortex will be explored for the following time epochs: 300-500ms, 600-800ms, 1500-2000ms, and 2000-2500ms, between jokes and non-jokes. The hypothesis is that jokes will show negative deflections at 300-500ms (N300-500) and 1500-2000ms (N1500-2000), and positive deflections at 600-800ms (P600-800) and 2000-2500ms (P2000-2500ms), when compared with nonjokes.

Hypothesis 4: Significant differences in activity in the posterior anterior cingulate cortex will be explored for the following time epochs: 300-500ms, 600-800ms, 1500-2000ms, and 2000-2500ms, between jokes and non-jokes. The hypothesis is that jokes will show negative deflections at 300-500ms (N300-500) and 1500-2000ms (N1500-2000), and positive deflections at 600-800ms (P600-800) and 2000-2500ms (P2000-2500ms), when compared with nonjokes.

Hypothesis 5: Significant differences in activity in the anterior superior temporal gyrus will be explored at 200-600ms between jokes and non-jokes. The hypothesis is that jokes will show a positive deflection at 200-600ms (P200-600) when compared with nonjokes.

Hypothesis 6: There will be no significant difference in activity in the lateral superior temporal gyrus at 600-2500ms between jokes and non-jokes, as a lateralization is not expected, because language is not part of the punchline, and therefore would not be part of the insight solution.

CHAPTER VI

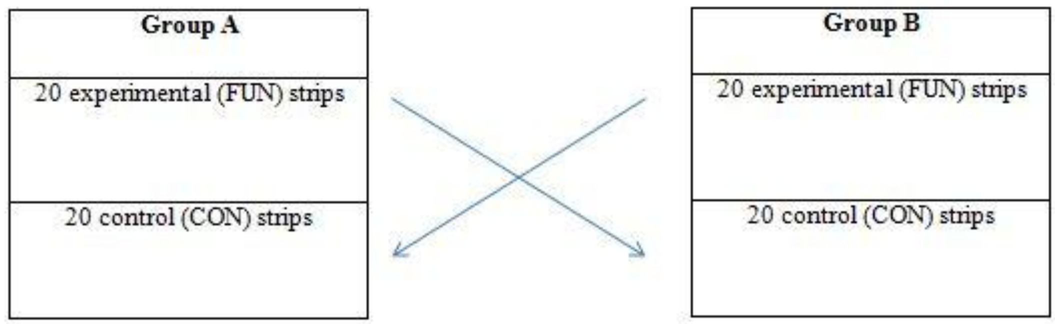
METHOD

Research Design

This study is a multivariate within subject design with one independent variable (IV) of two conditions. The experimental condition was made up of funny and surprising strips. The control condition was made up of strips that are neither funny nor surprising. In order to counterbalance their presentation, participants were randomly divided into two groups. Participants that were assigned odd code numbers were placed in Group A and those assigned an even code number in Group B. The control strips were altered versions of the experimental condition, the humorous aspect being modified into a neutral and coherent aspect. Each strip had two versions: a funny version (FUN) and an altered non-funny version (CON). Each version (FUN or CON) of the same strip belonged to one of two groups A and B. Every group was given 20 FUN strips and 20 CON strips, for a total of 40 trials for each participant (see Table 1). Participants of each group received the same preprogrammed randomized mix of experimental and control trials.

Table 1

Division of Trials in multivariate within subject design



Materials

The experimental materials included two questionnaires: A general information questionnaire and a handedness questionnaire. A funniness scale and a surprise scale were also provided. Jokes were used to elicit insight. Electrophysiological recording and reduction was used in this study.

***Stimulus*.** Many jokes were collected from the Cyanide and Happiness and The Far Side archives. Twenty jokes were then selected from each archive, resulting in twenty Cyanide and Happiness and twenty The Far Side jokes. Each joke was then cut into two parts: the first part and the punchline. The punchline of the joke was always a picture with no language. Cyanide and Happiness jokes were made of a series of strips that included language, followed by the punchline that was a picture with no language (see Figure 1). The Far Side jokes, on the other hand, were made of a word or sentence, followed by the pictoral punchline (See Figure 2). Each joke was also converted into a nonjoke where the second part was neither funny nor surprising. The nonjokes followed the same format as the jokes (see Figures 3 & 4). The stimulus was created and run through E-Prime software. The responses to the funniness and surprise scale, as well as to the prior knowledge question were saved via E-Prime software.

General information questionnaire. This questionnaire helped obtain information about the participants' age, gender, vision, prescribed medication, and alcohol or other recreational drugs taken recently. This information helped to control for factors that may add variability in the EEG recordings (Picton et al., 2000) (Appendix A). Based on the responses on this questionnaire, only the English-speaking, right-handed, healthy participants with normal-to-corrected vision were selected to proceed to the data collection phase.

Handedness questionnaire (Chapman & Chapman, 1987). Measuring handedness was essential to minimize variations during EEG data collection (Picton et al., 2000). Chapman and Chapman's (1987) measurement of handedness contained thirteen items and was established by Raczkowski, Kalat, and Nebes (1974). This scale had good internal consistency (Cronbach's α=.96) and high test-retest reliability (r=.96) (Appendix B). The item on the scale regarding baseball, "On which shoulder do you rest a bat before swinging" was discarded because it did not seem culturally relevant. All of the other twelve items served to identify the dominant hand of the participants. Handedness was a key aspect in the selection process. In order to decrease variability, only right-handed participants were chosen to complete the experiment.

Funniness Scale. To assess the degree of funniness, participants were asked to rate each strip after its presentation using a 1-item Likert scale. The sentence, "How funny was the strip?" was the phrasing used. The range of scores was from 1 (not funny at all) to 4 (very funny) (Appendix C).

Surprise Scale. To assess the level of surprise, participants were asked to rate each strip after its presentation using a 1-item Likert scale. The sentence, "How surprising was the strip?" was the phrasing used. The range of scores was from 1 (not surprising at all) to 4 (very surprising) (Appendix D).

Prior Knowledge of the Joke. To determine whether the participant had seen the joke before, A yes/no question was asked after the presentation of each strip. The sentence, "Have you seen this comic strip before?" was the phrasing used.

Electrophysiological data collection and reduction. The cap was placed in accordance with the 10-20 international system. The recordings were made on 32 electrodes mounted on an elastic cap. To control for ocular artifacts that can contaminate the EEG, horizontal and vertical electrooculograms (EOGs) were recorded (Croft & Barry, 2000). For the horizontal EOGs, also known as HEOG, electrodes were placed on the right and left of the outer canthi of the eyes (see Figure 5). The final HEOG signal was calculated from these two recordings. The vertical EOG (VEOG) was calculated from the difference between the neural potential above and below the left eye, placed in line with the pupil. In order to further decrease eye movements and thus artifacts, participants were encouraged to use eyeglasses instead of lenses while performing the task. The EOG recordings were also used as a marker for funniness. It was postulated that once participants smiled, the EOG would pick up the recording. The rational was that the EOG signal would allow us to pinpoint when insight occurred.

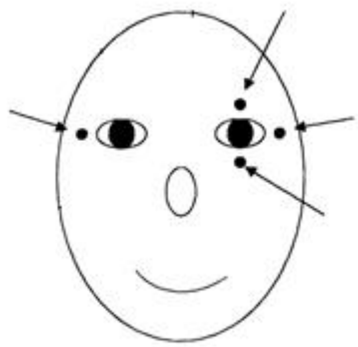


Figure 5. Brunia et al., (1989) electrooculogram placement scheme

Data was recorded using the shielding mode option in Pycorder software (Brain Products) since the room was not fully insulated. Both the EEG and the EOG signals were sampled at a rate of 256 Hz, and a digitally low-pass filter was set at a 52 Hz cut-off (Boksem & De Cremer, 2010). The reference used was Pz; however, it was re-referenced to an average mastoid reference later during the analysis (offline re-referencing). Impedance was kept below 25kOhm to ensure reliable EEG recordings.

The EEG continuously recorded during the stimulus presentation with markers allowing for ERP extractions. Each trial consisted of 200ms before the presentation of the punchline and 2500ms after the presentation. Epochs from 250ms to 500ms from Fp1, Fpz, Fp2, F3, Fz, and F4 were used to examine prefrontal event-related potential. Data between 300ms to 2500ms from Fz, FC1 and FC2 was used to examine event-related potential in the ACC. To inspect activity in the STG, data from Pz and Oz between 200ms and 600ms, and F7 and F8 between 600ms and 2500ms was used. Data from each participant was inspected. Those trials that were excessively contaminated by artifacts were rejected.

Informed Consent

Upon arrival to the first session, the participants were given an informed consent form (Appendix E) to clarify the purpose of the study, which had not been fully disclosed up until then. The participants were told that the aim of the study was to examine brain activity during insight. This sheet also explained the procedure of the experiment with the potential risks and benefits of this research study. Alternative procedures were given to the students, as required by the IRB upon use of the Psychology 101/201 pool. The sheet also reminded the students that they had the right to withdraw from the study at any point without any explanation and without any penalty. Students who did not want to participate in this study could either earn equivalent credit point by writing a brief report on an article from a psychological journal or by participating in another study. Personal identifiers (i.e., name and email) were collected from the participants to be able to contact them for the second session; however, this information was kept confidential. The information sheet indicated that the first forty participants to meet the requirements would be asked to complete the study. By signing the informed consent, participants chose whether they want to participate in the study. Participants were also informed that the data will be kept confidential to the fullest extent possible and all the information provided in reports could not be traced back to them. Raw data will be destroyed after seven years have elapsed.

Pilot Study

Before the experiment was conducted, a pilot study was conducted to test the appropriateness and the clarity of the instructions, as well as the funniness and level of surprise of the jokes given during the experiment. Five volunteers were used. Each participant went through the strips. Jokes that were considered not funny or not surprising by the majority of the volunteers were removed. The omitted jokes were then replaced by jokes that were rated as funny and surprising by the same volunteers. The phrasing of some ratings and instructions was altered in response to the pilot study.

Main Study

***Sample characteristics*.** Students were recruited from the Psychology 101/201 pool at the American University of Beirut. To decrease variability in the EEG data, only people between 18 and 25 years of age were selected for the study. Similar to other insight studies, forty healthy participants (20 men and 20 women) who had normal-to-corrected vision (Picton et al., 2000), were English-speaking and right-handed were recruited. A 1:1 ratio of men to women was acquired to decrease variability in the EEG recordings (Picton et al., 2000). Participants ranged from 18 to 22 years old (M=18.55). After completing the first session in which volunteers were asked to fill out the general information and the handedness questionnaires, the first twenty male and twenty female participants to meet the criteria needed for the study were selected for the second session. Students who completed the second session earned 1 extra credit in the Psychology 201 course. Data collection took place during the Spring 2014 academic semester.

Procedure

For recruitment, an advertisement was sent to the AUB Psychology 101/201 courses to start working on a subject pool for research purposes. The nature and purpose of the experiment was described in the advertisement. The advertisement also stated that only people between 18 and 25 years of age would be selected for the study. Interested students were asked to contact the co-investigator to schedule the first session. The experiment occurred over the course of two sessions.

Session one. The first session took place in the Psychology Lab in the Jesup Building, Room 107B, at the American University of Beirut. This session lasted about 10 minutes. Participants came to this session in groups.

Upon the signing of the informed consent form, participants received two questionnaires: the general information questionnaire and the handedness scale. Participants were then given a demonstration of the EEG set up and recording procedures to familiarize them with the protocol and reduce novelty effects. The researcher informed the participants that this technique would not put them at any health risk. The circumference of the participants' heads was then measured to ensure the use of the proper size cap in the second session. Participants were encouraged to ask any questions pertaining to the study and the procedure.

Session two. The first eligible twenty males and twenty females to complete the study were contacted and assigned to a schedule. Each participant carried out this session alone and at a different time. These sessions also took place in the Psychology Lab in 107B in the Jesup Building at the American University of Beirut. Volunteers were put randomly in one of the two groups A or B. Participants with an odd code number were assigned to group A, and those with an even code number to group B.

Participants were given again a short explanation of the EEG set up procedure. They were then seated in front of a computer screen. The experimenter, assisted by an undergraduate student, fixed the EEG cap on the head of the participant. Participants were told that the experiment had begun and were asked to minimize movement during the trials to obtain better EEG recording.

Participants were asked to enter the numerical code they were assigned in the first session. They read on the computer screen the instructions of how the experiment will unfold. Two practice trials were presented in order for participants to become acquainted with the experiment. Any questions or concerns about the EEG were answered by the experimenter.

All participants were presented with the same preprogrammed randomized mix of twenty experimental (FUN) and twenty control (CON) trials from their group. Each trial began with the appearance of a fixation dot in the middle of the screen. After two seconds, the first part of the strip appeared on the screen. This was either in the form of a sentence or a few frames that presented the first part of the trial. Upon pressing the space bar, the screen was cleared and the second part of the strip appeared. This was the punchline, which was in the form of a single language-free picture. The punchline remained on the screen until the participant pressed the space bar. After each strip, the participant was asked to fill out the on-screen funniness scale, the surprise scale, and whether they had previously seen the strip. Each of these scales remained on the screen until the participant entered their rating. Following the completion of the scales, the next trial began (see Figure 6). After the session was over, participants were thanked and asked what they thought of the stimulus. Some participants expressed joy to have been part of a fun experiment. Others expressed frustration as they expected the jokes to be funnier, or because they did not understand the jokes.

CHAPTER VII

RESULTS

This study was set out to test the specific depolarization changes associated with passive insight through the use of jokes. This chapter presents the behavioral results from the pilot study and the electrophysiological results of the main study.

Pilot Study

As a manipulation check that participants would actually find the jokes presented funny and surprising, we set out to test for any significant differences between jokes and nonjokes in terms of funniness and level of surprise. Five pilot participants rated the final jokes and non-jokes to be used in the study. Twenty jokes and twenty non-jokes were rated for levels of funniness and surprise on a scale from 1 to 4.

Statistical assumptions. The assumption of normality was assessed for all ratings using standardized scores (z-scores) of skewness and kurtosis. Variables with z-scores above |3.29|, corresponding to the $p>.001$ criteria, were considered non-normally distributed. All z-scores were below |3.29|, indicating normal distributions.

Univariate and multivariate outliers for the ratings were inspected. Standardized scores were examined for univariate outliers. Scores with z-scores above |3.29|, corresponding to the $p>.001$ criteria, were considered outliers. None of the z-scores were greater than |3.29|, meaning that there were no univariate outliers in the data. Multivariate outliers were examined using Mahalanobis distance at $p<.001$. None of the cases scored higher than $\chi^2(10)=29.59$, which implies that there were no multivariate outliers.

Descriptive statistics and Mann-Whitney U test. The aim was to see if there was a significant difference in the funniness and level of surprise between jokes and non-jokes. There were no missing values in the ratings. Since it is difficult to trust normality tests with small sample sizes, a non-parametric test was used. A Mann-Whitney U was conducted to evaluate this hypothesis. Nonjokes (M=1.5, SD=0.17) were significantly less funny on average than jokes (M=3.51, SD=0.11) z =-2.62, p<.05. They were also significantly less surprising (M=1.72, SD=0.20) than jokes (M=3.64, SD=0.20) z =-2.61, p<.05.

The results of the pilot study confirmed hypothesis 1, which states that the jokes would be seen as funny and surprising, and nonjokes as neither funny nor surprising in the main study. Insight, therefore, would be expected for the jokes but not for the nonjokes.

Electrophysiological Results

Analysis of the electrophysiological results recorded by the EEG was carried out. In this section, steps of data preprocessing are presented first, followed by the statistical assumptions and the analysis of each of the event-related potentials separately.

Data preprocessing. ERP analyses were carried out using Matlab. The signal was filtered offline using a 40Hz low pass filter, a 48dB/octave attenuation, a 53Hz high pass filter and a 50Hz notch filter. Noisy channels were dismissed. An Independent Component Analysis (ICA) was carried out. All components corresponding to artifacts were removed from the continuous EEG data. Artifacts caused by ocular movements were also removed. Finally, all channels were re-referenced to an average reference. Statistical analysis was then carried out using SPSS.

Data from one participant included too many artifacts and was therefore deleted. As a manipulation check, ratings from each subject were inspected. Only jokes that were rated >2 on funniness and level of surprise were kept in the analysis. Similarly, only nonjokes that were rated <3 on funniness and level of surprise were kept. This was to ensure that an insight event could occur. The number of trials that were removed from the analysis differed between participants, ranging from 8 to 21 trials. This is common practice in neuroscience, as it ensures a cleaner recording and analysis. For this reason, only stimuli that had not been previously seen by the participant were analyzed. After the manipulation checks, similar trials (jokes and nonjokes) were averaged out for each participant. Epochs were then extracted between 250ms and 500ms for Fp1, Fpz, Fp2, F3, Fz, and F4, between 300ms and 2500ms for Fz, FC1 and FC2, between 200ms and 600ms for Pz and Oz, and between 600ms and 2500ms for F7 and F8. Data from Fp1, Fpz, Fp2, F3, Fz, and F4 was used to examine prefrontal event-related potential. Data from Fz, FC1 and FC2 was used to examine event-related potential in the ACC, whereas data from Pz, Oz, F7 and F8 was used to inspect activity in the STG (Qiu et al., 2008a). The EOG signals that were to be used as a manipulation check were also inspected. The EOG signals from the joke stimuli and the nonjoke stimuli were equally noisy. They could not be further analyzed or used as a manipulation check. As a result, they were discarded.

Statistical assumptions. Five paired samples t-tests were conducted in total, one pertaining to each analysis. For all analyses, the within subject variable was the type of stimulus (joke and nonjoke). The common statistical assumptions for the analyses are described together. The statistical assumptions that are specific to each analysis are then presented along with the results of the analyses.

Univariate and multivariate outliers. Standardized univariate outliers for the electrodes used at their respective time epochs were inspected using the criteria presented in the pilot study, at a cut-off point of |3.29|. There were five univariate outliers in total: one in the nonjoke condition for Fz between 1500ms and 2000ms, one in the joke condition for Fz at 2000ms-2500ms, one in the nonjoke condition for Fz between 2000ms and 2500ms, one in the nonjoke condition for Fc1 and Fc2 average at 2000ms-2500ms, and one in the joke condition for F8 between 600ms and 2500ms. Univariate outliers throughout the data for all the analyses constituted 1.95% of the sample. These cases were retained since the z-scores were not substantially high, ranging from absolute values of 3.37 to 4.52. Multivariate outliers were inspected using Mahalanobis distance with a $p<.001$ criteria. None of the cases scored higher than $\chi^2(22)=48.27$, indicating an absence of multivariate outliers.

Prefrontal cortex. Recordings from Fp1, Fpz, Fp2, F3, Fz, and F4 between 250ms and 500ms were used to study possible prefrontal area activity. Data from these six electrodes were averaged, as is commonly done in the literature (e.g., Coulson & Lovett, 2004; Sandkühler & Bhattacharya, 2008). A paired sample t-test was carried out for the average of the electrodes. The assumptions for the t-test and the results are presented below.

<u>Normality.</u> The assumption of normality was assessed for the difference variable using Kolmogorov-Smirnov test of normality. The K-S tests were non-significant, indicating that the assumption of normality was met.

<u>Paired-sample t-test.</u> Results indicated that there was no difference between jokes and nonjokes on the prefrontal cortex between 250ms and 500ms, $t(38)=-1.54$, $p>.05$. Hypothesis 2, which states that the prefrontal cortex is not implicated in insight, but rather in attention and awareness required to complete the task, was thus supported.

Anterior cingulate cortex. Recordings from Fz, FC1, and FC2 were analyzed between 300ms and 2500ms for the ACC’s role in insight. As in previous studies, FC1 and FC2 were averaged together, and the average was used in the analysis (e.g., Mai et al., 2004; Qiu et al, 2008a). Four time epochs were used in the analysis: 300ms-500ms, 600ms-800ms, 1500ms-2000ms, and 2000ms-2500ms. The assumptions were checked, then two paired samples t-tests were conducted.

Normality. The assumption of normality was assessed for the difference variables using Kolmogorov-Smirnov test of normality. The assumption of normality was met for all difference variables.

Paired-sample t-tests for Fz. To control for the family-wise error rate, a Bonferroni correction was used. The *p*-value was therefore adjusted to a $p<.0125$ criterion. As can be seen in table 2, results indicated that jokes showed significantly more negative depolarization than nonjokes at 300-500ms $t(38)=-2.73$, $p<.0125$, d=.89. There was, however, no significant difference between jokes and nonjokes at 600-800ms. Jokes showed a significantly more positive depolarization than nonjokes at 1500-2000ms $t(38)=2.77$, $p<.0125$, d=.90 and at 2000-2500ms $t(38)=2.89$, $p<.0125$, d=.94. The frontocentral ACC was therefore found to be implicated with insight at 300-500ms and at 2000-2500ms. The hypothesis was not confirmed altogether. While there was indeed a negative depolarization at N300-500 and a positive one at P2000-2500, there was no difference in depolarization between jokes and nonjokes at 600-800ms. Moreover, the deflection at 1500-2000ms was of positive polarity (P1500-2000), as opposed to the negative depolarization (N1500-2000) that was expected.

Table 2

Paired Samples Test for Fz

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Joke fz – Nonjoke fz 300ms_500ms	-1.61	3.70	.59	-2.81	-.41	-2.73	38	.010
Pair 2	Joke fz – Nonjoke fz 600ms_800ms	-1.05	3.66	.59	-2.24	.13	-1.79	38	.081
Pair 3	Joke fz – Nonjoke fz 1500ms_2000ms	2.07	4.68	.75	.56	3.59	2.77	38	.009
Pair 4	Joke fz – Nonjoke fz 2000ms_2500ms	2.55	5.51	.88	.76	4.34	2.89	38	.006

Paired-sample t-tests for FC1&FC2. The family-wise error rate was controlled for using a Bonferroni correction. The *p*-value was adjusted to a $p<.0125$ criterion. The results indicated that jokes were not significantly different than nonjokes at any time epoch for FC1&FC2 (see Table 3). The posterior ACC was not found to be implicated in insight, in this study.

Superior temporal gyrus. Recordings from Pz and Oz between 200ms and 600ms were averaged out to study the role of the superior temporal gyrus in line with previous studies (e.g., Jung-Beeman et al, 2004; Qiu et al., 2006a; Zhang et al., 2011). To examine possible lateralization, F7 and F8 between 600ms and 2500ms were compared. Two paired sample t-tests were carried out. The assumptions for the t-tests and the results are presented below.

Normality. The assumption of normality was assessed for the difference variables using Kolmogorov-Smirnov test of normality. The K-S tests were non-significant, indicating that the assumptions of normality were met.

Paired-sample t-test. Results indicated that there was no significance between jokes and nonjokes for Pz and Oz between 200ms and 600ms, $t(38)=1.19$, $p>.05$, showing that the superior temporal gyrus was not implicated at an early stage. When comparing F7 and F8, the results showed a left-side polarization between 600ms and 2500ms, $t(38)=5.32$, $p<.05$, d=1.73 (Table 4). Hypothesis 6 was therefore not supported, as the results indicated a left-brain lateralization.

Table 4
Paired Samples Test for Pz_Oz and F7_F8

		Paired Differences				t	Df	Sig. (2-tailed)
		Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1	Joke pz_oz – Nonjoke pz_oz 200ms_600ms	2.49	.40	-.33	1.28	1.19	38	.24
Pair 2	Joke f7 – Joke f8 600ms_2500ms	12.07	1.93	6.37	14.20	5.32	38	.000

CHAPTER VIII

DISCUSSION

Insight is an event experienced by most people on a regular basis. Despite its ubiquity in natural settings, neuroscientific research about it remains torn (Dietrich & Kanso, 2010). The existing EEG/ERP studies on insight show many discrepancies in the results. This is supposedly due to the nature of the tasks used to study insight. To date, only a handful of studies have used a methodology similar to the one used in this study. In the present study, we used jokes to explore the spatiotemporal activation patterns underlying insight. In this chapter, we discuss the results of the study.

Jokes that were used in the study were found to be surprising and funny, while nonjokes were found to be neither funny nor surprising, as was seen from the data in the pilot study. It was important to establish this prior to the beginning of the main study, to ensure that insight would occur during jokes but not during nonjokes.

Electrophysiological results showed no difference in activity in the prefrontal cortex between jokes and nonjokes. In the frontocentral anterior cingulate cortex, jokes elicited a negative depolarization at 300-500ms and positive depolarizations at 1500-2000ms and 2000-2500ms. Contrary to what was expected, jokes did not elicit a difference in depolarization at 600-800ms. The posterior anterior cingulate cortex did not show any difference in depolarization between jokes and nonjokes at any of the time intervals (300-500ms, 600-800ms, 1500-2000ms, and 2000-2500ms). As for the superior temporal gyrus, it did not show any difference in depolarization between jokes and nonjokes at 200-600ms. However, the data indicated a left-side depolarization at 600-2500ms. These results are discussed in the following paragraphs.

Jokes and nonjokes yielded the same ERPs in the prefrontal cortex. These findings suggest that the prefrontal cortex may not be implicated in insight. This study's findings contradict many ERP and fMRI studies. The literature does not converge on the matter, as some studies demonstrate prefrontal cortex activation, while others do not. For instance, Luo et al. (2004) implicated a left lateral prefrontal cortex activation in insight. Other studies emphasized the role of the right ventral prefrontal regions (Aziz-Zadeh et al., 2009; Rose et al., 2002; Rose et al., 2005). Bechtereva et al. (2004) suggested that a bilateral activation of the prefrontal cortex is integral for insight to be achieved. Still, several other studies found no significant effect of insight on the prefrontal cortex (Jung-Beeman et al., 2004; Kunios et al., 2006, Luo et al., 2004; Starchenko et al., 2003). Some of these studies suggest that the prefrontal cortex's role lies in the difficulty of the task and not in insight (Luo et al., 2004; Starchenko et al., 2003). Luo et al. (2004) stated that non-insightful difficult solutions activate the prefrontal cortex the same way that insightful solutions do. The results of our study regarding the prefrontal cortex converge with the latter conclusion. Although we did not measure it, it is assumed that both jokes and nonjokes offered the same level of difficulty in understanding the ending of the joke, and required the same level of awareness and attention. Because of this, both jokes and nonjokes had the same level of activation of the prefrontal cortex. This study therefore provides no evidence that the role of the prefrontal cortex is linked to insight, but instead to the attention, awareness, and high level of difficulty required to complete a task.

The anterior cingulate cortex is of particular importance in the study of insight as well as the study of humor. Most studies show a link between insight and the activation of this region (Dietrich & Kanso, 2010). The current study showed a negative depolarization in the frontocentral anterior cingulate cortex at 300-500ms, as seen in Figure 7. This is in agreement with many insight studies. Such studies consider negative depolarizations within that range to be the N400, a depolarization known to be associated with incongruences. Negative deflections at N320 (Qiu et al., 2006a), N380 (Mai et al., 2004; Shen et al., 2011), N300-500 (Xing et al, 2012), and N320-500 (Shen et al., 2013) have been observed. It was speculated in these studies that this negative depolarization reflects the cognitive conflict that results from breaking the mental impasse that often precedes insight. Humor studies reflect similar findings. Studies on humor have found a strong N400 depolarization related to jokes but not to nonjokes (Coulson & Kutas, 2001; Coulson & Lovett, 2004; Coulson & Severens, 2007; Coulson & Williams, 2005; Derks et al., 1997; Du et al., 2013). Since joke endings were more surprising and unexpected than nonjoke endings, the authors of the humor studies suggested that this negative deflection reflects that the participant registered the surprise in joke comprehension. The surprise in the joke found in humor studies and the cognitive conflict resulting from breaking the mental impasse could be two sides of the same coin. We suggest in this study that the surprise in the joke could be, in fact, the cognitive conflict that results when the mental impasse is broken. We speculate that the N300-500 found in this study therefore reflects the surprise in the joke, which is another facet to the cognitive conflict resulting from the overcoming of the mental impasse.

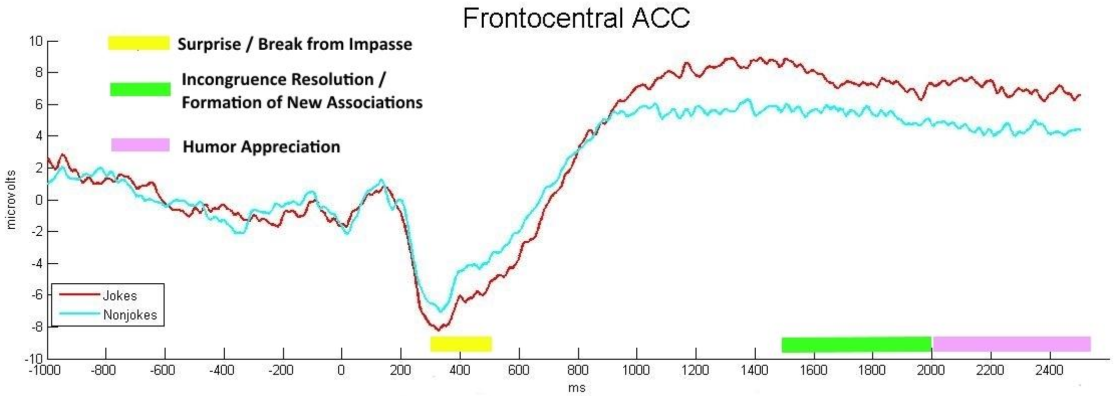


Figure 7: Time locked ERPs across the frontocentral anterior cingulate cortex. The difference wave between jokes and nonjokes is illustrated. The timeframes for the surprise, formation of novel associations, and humor appreciation are highlighted.

The formation of novel associations after the mental impasse was also explored in this study. Neither deflections associated with novel association in the frontocentral anterior cingulate cortex (N1500-2000 and P600-800) were shown in our study. This contradicts other findings. Qiu et al. (2008b) speculated that N1500-2000 is implicated in the formation of novel associations. Other studies reported that positive deflections at P730 (Qiu et al., 2008a; Zhang et al., 2011) and P600-1100 (Qiu et al., 2006b) were associated with the formation of novel associations instead of N1500-2000. The current study, however, showed a positive deflection at P1500-2000 (see Figure 7). Because different timeframes and direction of deflections within the broader timeframe of 600-2000ms have been associated with the formation of novel associations, it is assumed that the P1500-2000 in this thesis reflects, in fact, the formation of novel associations after the mental impasse is broken. Since the different studies exploring this timeframe did not use jokes as a stimulus to study insight, it is argued that the novel type of stimulus accounts for the specific polarity and timeframe of the deflection found in our study (P1500-2000). Studies on humor also explore this timeframe. Tu et al. (2014b) associated the positive deflection

P1000-1600 with incongruence resolution. As with the N400, findings from insight studies and humor studies can be merged. Incongruence resolution can be redefined as a formation of novel association, once the punchline is given. It is therefore speculated, in this study, that the P1500-2000 that was found is associated with the formation of the novel association, or incongruence resolution, which allowed participants to understand the punchline.

Still within the anterior cingulate cortex, the current study showed a positive deflection at P2000-2500, as can be seen in Figure 7. This finding does not mirror any findings within the insight studies except one, which happens to also be a study on insight using jokes. Tu et al. (2014b) associated a positive deflection in the ACC at P2000-2500 with humor appreciation. These findings were replicated in the current study. Since both studies used jokes as stimuli, and since none of the non-humorous studies found any difference in activity at 2000-25000ms, it is safe to assume that this positive deflection indeed reflects humor appreciation, as insight is assumed to have already been achieved by then. It is known that people experience positive affect after insight. In the case of jokes, positive affect that is already experienced after insight is enhanced, as the stimulus itself is humorous. Therefore one can also speculate that the positive affect that is experienced once insight is achieved is enhanced by the type of the stimulus itself, a joke in this case, which in turn leads to the ability to detect the positive affect in the anterior cingulate cortex in the form of a positive deflection P2000-2500. However, this is nothing but mere speculation, since this specific timeframe (2000-2500ms) is still quite new to the field. Since both studies that found this specific result were insight studies using jokes, it is likely that P2000-2500 is in fact associated with humor appreciation, especially since insight is expected to have already been achieved within the 600-2000ms timeframe.

The posterior anterior cingulate cortex did not show any differences in activity for the timeframes (300-500ms, 600-800ms, 1500-2000ms, and 2000-2500ms). Two studies have highlighted the involvement of the posterior anterior cingulate cortex, at the level of novel association formation. Zhang et al. (2011) reported that P730 in both parts of the anterior cingulate cortex is responsible for this novel association. Xing et al. (2012) stated that P500 was behind the formation of novel associations. The difference between the activation of the two different parts of the anterior cingulate cortex is not explained in the literature. The seeming lack of activity in the posterior cingulate cortex in the current study can be explained by the stringent nature of the Bonferroni correction. In fact, without this correction, the findings would have mirrored that of the frontocentral anterior cingulate cortex. We speculate that the variances between studies and lack of difference in the literature between the posterior anterior cingulate cortex and the frontocentral cingulate cortex are because the entire anterior cingulate cortex is activated during the process. However, the frontocentral electrodes are less sensitive to noise due to their position than the posterior electrodes (Luck, 2005). The frontocentral ACC, in this case, would be more likely to show deflections than the posterior ACC. Because of the trend that is visible in the results of the posterior ACC, we suggest that the ACC as a whole is implicated in the cognitive conflict that results from breaking the mental impasse, in the formation of novel associations, and in humor appreciation.

There was no difference in depolarization between jokes and nonjokes in the early stage (200-600ms) in the superior temporal gyrus. This converges with some of the research in the literature, but not others. Those that found early stage activation in the STG have implicated the superior temporal gyrus in facilitating the formation of remote associations (Qiu et al., 2006a; Sandkühler & Bhattacharya, 2008; Shen et al., 2011; Qiu et al., 2008a, Shen et al., 2013; Zhang et al., 2011). However, not all studies in the literature found a role for the STG in insight (Danko et al., 2003; Kounios et al;, 2006; Lang et al., 2006; Lavric et al., 2000; Mai et al., 2004; Qiu et al., 2008b). It is possible, therefore, that the role of the superior temporal gyrus at an early stage is not the product of insight, but rather a product of the type of stimulus used in the paradigm.

To test this, we investigated further the role of the superior temporal gyrus by looking at the later deflection of the STG (600-2500ms) that is associated by some researchers with the right-brain theory of insight. The right-brain theory is a small trend within the study of insight that implicates the right side of the brain, namely the superior temporal gyrus, to insight (Kounios & Beeman, 2014). More specifically, the right hemisphere has been implicated, by this line of reasoning, with insight-related coarse semantic coding and internally focused attention that occurs before and during problem solving. A handful of studies have shown right hemispheric dominance in the STG within 600-2500ms (Jung-Beeman et al., 2004; Kounios et al., 2008). We propose, as does the majority of researchers in the field, that this right hemispheric dominance is not due to insight, but rather to the language-based nature of most of the paradigms used in insight studies. Contrary to these studies, the current research showed a left hemispheric dominance at 600-2500ms. This replicates one other study in the literature that also reported a left hemispheric dominance (Qiu et al., 2008a). They explained this dominance as coming from the strengthening of comprehensive associations, in line with Luo and Niki (2003)'s study, which found that a lateralization is due to the efforts to "compare, integrate and map different attributes of relationships between concepts that often do not bear surface similarities" (p. 105). This in turn would lead to strengthening rich associations that enable the person to solve the task (Qiu et al., 2008a). In this case, these rich associations enabled participants to understand the punchline by making an association between it and the first part of the joke. Findings linking the left hemisphere to the same task that is normally related to the right hemisphere calls into questioning the right-brain theory of insight. They posit instead that an activation of the STG is found in insight, but that the lateralization of this activation depends solely on the type of task used to study insight.

This study allowed for an in-depth exploration of insight, as well as humor. The prefrontal cortex was found to not be linked to insight, but rather to extraneous variables pertaining to the prefrontal cortex required to complete certain tasks. It also confirmed previous results regarding the anterior cingulate cortex. The N300-500 depolarization was found to reflect the cognitive conflict that comes from a break in the mental impasse, also seen as the surprise in the joke. The P1500-2000 deflection, as opposed to the P600-800, on the other hand, reflected incongruence resolution, which is thought to be the same as the formation of new associations, once the mental impasse is broken. Only the frontocentral anterior cingulate cortex showed activity. The posterior anterior cingulate cortex showed a trend that mirrors that of the frontocentral anterior cingulate cortex. This could be due to the low sensitivity of the posterior region to capture differences. The literature shows no explanation for an activation of one part of the anterior cingulate cortex and not the other. Within the superior temporal gyrus, this study showed no activation in the early stage of insight (200-600ms). It did, however, show a negative deflection at N600-2500, which is associated with the strengthening of rich association. This strengthening allows for a proper solution of the task. The lateralization in the STG was speculated to be related to the type of task used to study insight, and not to insight itself. As for humor, this study showed that humor appreciation occurred as a result of a positive deflection at 2000-2500ms in the ACC.

Unlike the two studies on humor that tangentially target insight, this study used jokes to study insight. It was therefore possible to discern, because of this approach, which deflections are due to insight, which are related to humor, and which are the product of the specific type of stimulus being used. It also allowed us to merge components that have been found in humor studies with those found in studies on insight. This study presented a unique and novel method to study insight in a manner that can strip the results down to those that are associated with insight alone. Studying insight using jokes with a non-verbal punchline allows us to exclude depolarizations related extraneous variables in the prefrontal cortex, possibly those pertaining to attention, awareness, and level of difficulty from the results. More importantly, it also allows us to minimize language-related deflections, which have been one of the biggest constraints in the study of insight up until now.

Limitations and Future Research

This study presents a new method to study insight. It offers several advantages. First, language depolarizations are minimized due to the pictorial nature of the punchline. Second, jokes are easy to come by. It is also easy to change their endings into non-insightful endings. This offers a very large pool of tasks available for researchers to use. Third, this study provides a means to exclude depolarizations that are due to extraneous variables, mainly the type of the task. Fourth, there is a very short amount of time needed to understand jokes, which decreases the total time needed for a session to occur. Fifth, insight will occur from the point when the participant is presented with the punchline. Thus, the approximate timeframe in which insight occurs is known. Finally, researchers are able to identify when participants understand a joke, since they will rate the joke as funny and surprising. Therefore there is no need to rely on self-report on whether they achieved insight. Nevertheless, this study still is not without limitations.

The main limitation is with the nature of the jokes themselves. The jokes that were used were made for the American population. They were not of perfect fit for the Lebanese culture. Even though the sample used was a group of English speaking students, the jokes were not necessarily understood, because of their cultural connotations. As a result, some trials did not pass the manipulation check, because the participants did not understand them, as some participants stated during the debriefing. Ideally, we should have used Lebanese jokes in Lebanese Arabic. However, there was not a big enough pool from which to choose. Moreover, the trade-off would have been that many participants would have already heard the joke, and insight would not have occurred during the EEG session. These trials would have been discarded. Later studies could attempt to find jokes that are more culturally relevant to their sample while ensuring that they are novel enough for most of the population for insight to occur. Another related limitation is that there is no guarantee that jokes will be understood by everyone in the sample. People have different tastes in jokes, and insight jokes with a pictorial punchline would make it harder to find a good target sample, regardless of cultural differences. Another possibility would be to use entirely pictorial stimuli. However, we were not able to find enough jokes that fit this category and are insight producing. It could be suggested that a cartoonist is hired to create entirely pictorial stimuli to eliminate the use of language completely.

The use of the EEG offers a great advantage that is unmatched in any other neuroimaging technique: a precise temporal resolution. However, its main limitation remains in the inability to provide the exact location responsible for the electric activity. Because of this technique, more trials were also needed to provide a more accurate waveform. Two possibilities exist for future studies. First, a simultaneous EEG and fMRI study could be used to study insight. This would ensure an excellent temporal resolution without having to lose any precision in the spatial resolution. Second, more trials could be used to provide a more accurate waveform.

As with all insight studies, there is no method to know the exact millisecond in which insight occurs. In our case, jokes could have been understood at any point after the pictorial punchline was shown. Since the EEG records ERPs at a millisecond rate, even a delay of a few milliseconds could change the data. Different jokes might have taken different times to understand. Even though the typical timeframes were taken from previous studies for insight to occur, it resulted in timeframes that are not correct within the millisecond range for which EEG's are used. We attempted, in this study, to detect this specific timeframe using EOG signals. Our rationale was that participants would smile for jokes, which in turn would show up in the EOG signal. However, the EOG signals for both types of stimuli were equally noisy and could not be used as a manipulation check. We speculate that it is because participants were having facial movements for both types of stimuli, i.e., smiling or looking deceived. Future studies might ask participants to press a button as soon as they understand the joke. This would decrease the time variability between trials and therefore provide a more precise timeframe. However, the proposed solution is not without risks. It could make the averaging of the trials as problematic as estimating the typical timeframes. This is because certain stages of insight might take longer for some trials or participants but not for others.

Our experiment paves the way for improvements on a new method of studying insight that proved to be successful. However, the results of this study should be taken with caution. This study explores passive insight. Studies using active insight might yield different results that would clarify components needed for active insight to occur. To clarify the neural mechanism of insight, future studies using jokes could compare passive insight, i.e., understanding a joke, with active insight, i.e., coming up with a funny ending to the beginning of a joke, and comparing both with a nonjoke. Our novel method and results herald future research to study insight in an improved manner, in hopes to help unveil the components related to the stages of humor, and more importantly the specific mechanisms that are responsible for achieving insight.

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Appendix A

American University of Beirut

P.O. Box 11-0236

Riad El Solh, 1107 2020

Beirut, Lebanon

Research Project

General Information

Participant's Code: _________________

Please fill out the following:

Age: ____________________

Gender: ☐ Female ☐ Male

Do you have normal vision (with correction)? ☐ Yes ☐ No

Are you taking any prescribed medication that affects your cognitive processes?

☐ Yes ☐ No

Did you take alcohol or other recreational drugs 24 hours prior to the experiment?

☐ Yes ☐ No

Appendix B

American University of Beirut
P.O. Box 11-0236
Riad El Solh, 1107 2020
Beirut, Lebanon

Research Project
Handedness Scale

Participant's Code: ___________________

Please indicate below which hand you ordinarily use for each activity.

With which hand do you:

1. draw?	1. Left	2. Right	3. Either
2. write?	1. Left	2. Right	3. Either
3. use a bottle opener?	1. Left	2. Right	3. Either
4. throw a snowball to hit a tree?	1. Left	2. Right	3. Either
5. use a hammer?	1. Left	2. Right	3. Either
6. use a toothbrush?	1. Left	2. Right	3. Either
7. use a screwdriver?	1. Left	2. Right	3. Either
8. use an eraser on paper?	1. Left	2. Right	3. Either
9. use a tennis racket?	1. Left	2. Right	3. Either
10. use a scissors?	1. Left	2. Right	3. Either
11. hold a match when striking it?	1. Left	2. Right	3. Either
12. stir a can of paint?	1. Left	2. Right	3. Either
13. On which shoulder do you rest a tennis racket?	1. Left	2. Right	3. Either

Appendix C

American University of Beirut

P.O. Box 11-0236

Riad El Solh, 1107 2020

Beirut, Lebanon

Research Project

Funniness Scale:

Please rate how funny you think the comic strip was:

1- Not funny at all 2-Not funny 3-Funny 4-Very Funny

Appendix D

American University of Beirut
P.O. Box 11-0236
Riad El Solh, 1107 2020
Beirut, Lebanon

Research Project

Surprise Scale:

Please rate how surprising you think the comic strip was:

1- Not surprising at all   2-Not surprising   3- Surprising   4-Very surprising

Appendix E

Informed Consent Form

American University of Beirut

P.O. Box 11-0236

Riad El Solh, 1107 2020

Beirut, Lebanon

CONSENT TO SERVE AS A PARTICIPANT IN A RESEARCH PROJECT

Research Project: *Funny Brain Activity: An ERP Analysis of Insight*

Project Director: *Arne Dietrich, Ph.D.*

Professor of Psychology, Department of Psychology, AUB

ad12@aub.edu.lb

01-350000 Ext. 4369

Research Investigator: *Zeina H. Yaghi*

Graduate Student of Psychology, Department of Psychology, AUB

zhy03@aub.edu.lb

03-157561

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*We are asking you to participate in a **research study**. Please read the information below and feel free to ask any questions that you may have.*

The study will take place in Jesup 107. This informed consent ONLY applies to this site (Jesup 107).

Announcements about the study could be communicated to you through your course instructors, through flyers posted on the departmental bulletin board, or on the Department's website.

Only forty participants will be recruited for this study.

Nature and Purpose of the Project:

Achieving a clear and sudden solution following a task is an experience that people sometimes reach after being stuck in a problem-solving situation. This experience is known as insight or the A-ha! moment. The purpose of this study is to examine brain activity during insight. Brain activity can be picked up by a technique called electroencephalography (EEG). Insight will be studied using comic strips.

Explanation of Procedures:

As a research participant, you will have to read this information and consider carefully your participation. The experiment is carried out across two sessions.

In the first session, you will receive a personal information form to fill out. This form asks for personal information, such as the use of drugs and alcohol. Along with the personal information form, you are kindly asked to fill out a scale: the handedness scale which helps in the analysis of the brain activity. After that, the investigator will briefly explain how the second session will take place. Instructions for going through the experiment are demonstrated prior to the actual data acquisition of the brain activity.

It is expected that your participation in this experiment will not take more than 20 minutes in the first session. The second session will last for 35-40 minutes. The experimenter will contact you to schedule this session.

In the second session, you will then be asked to go through a series of comic strips on a computer. Some of these comic strips will be funny and surprising; others will be not funny and not surprising. Your brain activity will be recorded during the session using an electroencephalogram (EEG). After each comic strip, you will be asked to fill out a funniness scale and a surprise scale. You will also be asked if you have previously seen the comic strip. You will be video-recorded during the second session. This will serve to double-check whether you found the strip funny and/or surprising.

Your name will be asked and your information will be kept confidential. Only the project director and the research investigator will have access to your personal data. All results will be kept in a locked cabinet in the office of the research collaborator for a period of seven years after which the data will be shredded and permanently destroyed.

Potential Discomfort and Risks:

The EEG records ongoing brain activity that you produce naturally. Thus, the EEG is safe equipment and has little to no possible health risks. You may experience little discomfort as the electrodes are applied but the recording itself is painless. Thus, there are no more than minimal risks associated with participation in this experiment, although the possibility of some unforeseeable risks exists.

Potential Benefits:

The potential benefit is that you will participate in a study that will contribute to the fields of Neuroscience and Psychology. The results of this study will help understand the process of insight from a neurological and cognitive perspective.

Costs/Reimbursements:

Your participation in this experiment incurs no costs. You will receive 1 extra point on your final Psych 201 grade upon the completion of the tasks of the experiment.

Exclusion Criteria:

Due to constraints in the use of the EEG, you cannot be included in the study IF you are not right-handed, if you have used drugs or alcohol in the last 24 hours, or if you have visual impairment that is not corrected.

Alternatives to Participation:

Should you decide not to participate in this study, you can choose to write a brief report on an article from a psychological journal to receive credit equivalent to 1% point added to your Psyc 202 class.

Termination of Participation:

Should you decide to give consent to participate in this survey, the project director co-investigator might disregard your answers if the results show that you have not abided by the instructions given at the top of each set of questions.

Confidentiality:

The results of your participation will be kept confidential to the fullest extent possible. This means that only the project director and co-investigator will know about your specific results, which will be anonymous, as the identifying information would be linked to the data you provided up until data are analyzed. Only information that cannot be traced to you will be used in reports or manuscripts published or presented by the director or investigator. Hard copy data will be kept in a locked cabinet in the office of the co-investigator for a period of seven years following the termination of the study. Raw data on data-recording systems will be kept in a password protected computer in the Psychology Lab. After the seven years have elapsed, the raw data will be shredded (hard copies) and deleted (soft copies).

Withdrawal from the Project:

Your participation in this survey is completely voluntary. You may withdraw your consent to participate in this research at any point without any explanation and without any penalty. You are also free to walk out of the experiment at any point in time without any explanation.

Who to Call if You Have Any Questions:

The approval stamp on this consent form indicates that this project has been reviewed and approved for the period indicated by the American University of Beirut (AUB) Institutional Review Board for the Protection of Human Participants in Research and Research Related Activities.

If you have any questions about your rights as a research participant, or to report a research related injury, you may call:

IRB, AUB: 01-350000 Ext. 5454 or 5445

If you have any concerns or questions about the conduct of this research project, you may contact:

Arne Dietrich: ad12@aub.edu.lb, 01-350000 Ext. 4369

Zeina Yaghi: zhy03@aub.edu.lb, 03-157561

Consent to Participate in this Research Project:

By consenting, you agree to participate in this research project. The purpose, procedures to be used, as well as, the potential risks and benefits of your participation have been explained to you in detail. You can refuse to participate or withdraw your participation in this study at any time without penalty. This information sheet is for you to keep.

I have read and understand the above information. I agree to participate in the research study.

___________________________________ ___________________________

Signature of Participant **Date**

Consent to be video-recorded during the Second Session:

By consenting, you agree to be videotaped during the second session. The purpose of this recording has been explained to you in detail. You can refuse to be video-recorded in this study at any time without penalty.

I have read and understand the above information. I agree to be video-recorded during the second session.

___________________________________ ___________________________

Signature of Participant **Date**

____

Printed Name of Research Director

_______________________________________ ________________________________

Signature of Research Director Date

INSTITUTIONAL REVIEW BOARD APPROVAL STAMP

Appendix F
Tables

Table 3

Paired Samples Test for FC1_FC2

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Joke fc1_fc2 – Nonjoke fc1_fc2 300ms_500ms	-1.02	3.01	.48	-2.00	-.042	-2.11	38	.041
Pair 2	Joke fc1_fc2 – Nonjoke fc1_fc2 600ms_800ms	-.43	3.10	.50	-1.43	.58	-.86	38	.395
Pair 3	Joke fc1_fc2 – Nonjoke fc1_fc2 1500ms_2000	1.22	3.61	.58	.05	2.39	2.12	38	.041
Pair 4	Joke fc1_fc2 – Nonjoke fc1_fc2 2000ms_2500	1.35	4.11	.66	.02	2.69	2.06	38	.047

Appendix G
Figures

Figure 1. Cyanide and Happiness jokes. An example of a Cyanide and Happiness joke with the first part of the joke followed by the punchline.

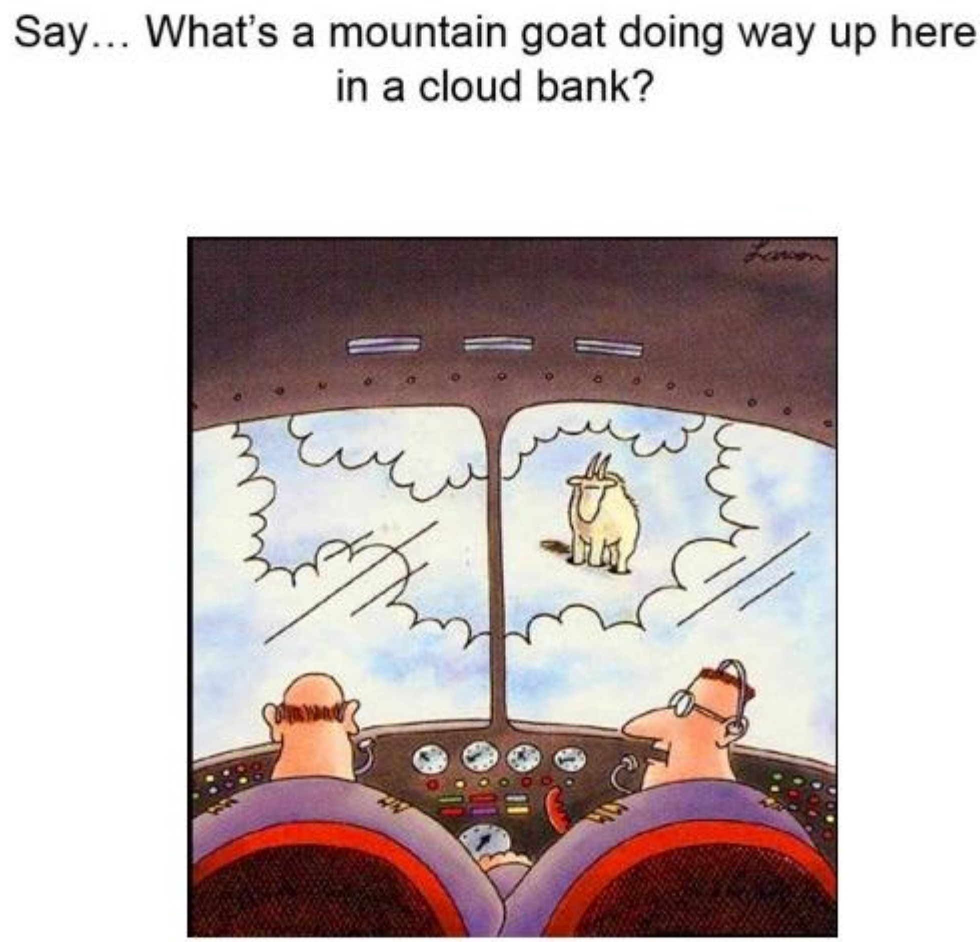

Figure 2. The Far Side joke. An example of a The Far Side joke with the first part of the joke followed by the punchline.

Figure 3. Cyanide and Happiness nonjoke. An example of a Cyanide and Happiness nonjoke with the first part followed by the not funny nor surprising ending.

Figure 4. The Far Side nonjoke. An example of a The Far Side nonjoke with the first part followed by the not funny nor surprising ending.

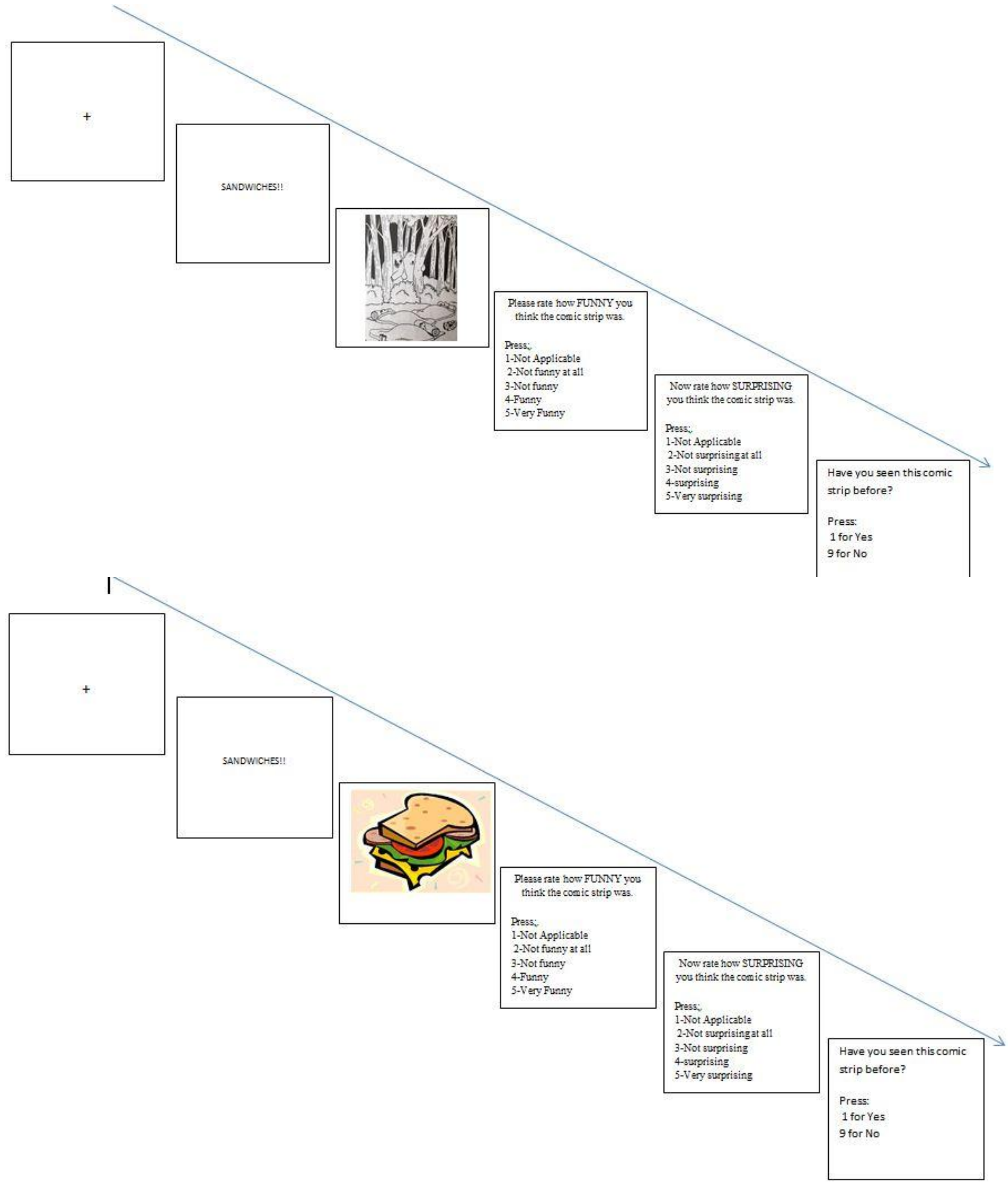

Figure 6. Procedure of FUN and CON trials