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A Study of EEG Signature Associated with Emotional and Stress Responses Due to Cyberbullying

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A STUDY OF EEG SIGNATURES ASSOCIATED WITH EMOTIONAL AND STRESS RESPONSES DUE TO CYBERBULLYING

by

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ABSTRACT

The human brain processes vital information regarding human feelings. Prior research has focused on the problems of underage bullying, workplace bullying, burnout, mobbing and, most recently, cyberbullying. Scholars have traditionally examined the adverse outcomes of cyberbullying using subjective measures of stress and emotion for decades. However, very few studies examined cyberbullying using objective measures like EEG. The main goal of this study was to explore the relationship between the brain's EEG, expressed by the power spectral density, and emotions and stress due to two types of cyberbullying, specifically: 1) social exclusion, and 2) verbal harassment. This research also examined how cyberbullying factors of social interaction and publicity affect the emotional and stress responses. EEG data were collected from twenty-nine undergraduate students, aged 18-22, using 10/5 EEG system with 64 channels. Each cyberbullying experimental condition was treated as an independent study. The first study investigated the effects of social exclusion on EEG activity and the related emotional and stress factors while playing a virtual ball-tossing game known as cyberball. EEG results showed significant differences in alpha and beta power in the right posterior brain regions due to social exclusion. There were also significant differences in beta and gamma power in the left anterior brain regions due to social exclusion. The results suggest that EEG activity in the left anterior brain region may be important to identify social exclusion. The second study utilized a hypothetical scenario presented as impolite or complimentary online comments. EEG results showed marginally significant differences in gamma power at right- and left- anterior and midline brain regions due to verbal harassment. The results suggest that changes in gamma power at anterior brain regions might play an essential role in the processing of verbal harassment information. Self-reported measures confirmed that verbal harassment was more distressing than social exclusion.

To my beloved father, Muslam Alhujaili

To my lovely mother, Fatimah Alhujaili

To my lovely wife, Roba Alhujaili

To my beloved brothers and sisters

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LIST OF ACRONYMS/ABBREVIATIONS

ANOVA	Analysis of Variance
ASR	Artifact Subspace Reconstruction
BCI	Brain-Computer Interface
CITS	Coping Inventory for Stressful Situations
DSSQ	Dundee Stress State Questionnaire
ECG	Electrocardiography
EEG	Electroencephalogram
ERP	Event-Related Potential
FFT	Fast Fourier Transform
PCA	Principal Components Analysis
PANAS	Positive and Negative Affect Schedule
PSD	Power Spectrum Density

CHAPTER 1: INTRODUCTION

1.1 Background

Imagine you bought a new house. You are so glad at that moment and decide to share your happiness with friends, and you post it online. All of a sudden, you are bombarded with unexpected hateful and mean comments. Your joy suddenly disappears, and feelings of anger and sadness take over. You try to suppress them, but they keep bubbling up. It looks as if it is never-ending. This scenario is only one among different types of cyberbullying that impact human well-being and emotions negatively.

Recently, the issue of cyberbullying has received significant attention among researchers due to the increasing number of verbal and non-verbal aggressive acts in social media and the dangers associated with them. Cyberbullying has destructively led to many negative emotional and physical impacts on people. Sometimes it has been indicated as a causal factor in suicidal attempts (Elgar et al., 2014). Therefore, cyberbullying is turning computers into a destructive machine.

Now, more than ever before, it is becoming accepted among researchers that cyberbullying causes harm to both the victim and perpetrator of cyberbullying (Kowalski et al., 2014; Patchin & Hinduja, 2006; Slaninova et al., 2011). It has been shown that people who are cyberbullied can feel the negative emotions of sadness, frustration, and anger which in turn can have physical effects (Hinduja & Patchin, 2010a). This emotional impact varies based on the cyberbullying type that the target experiences and individual differences (Ortega et al., 2012). The impact is also linked to how the brain deals with cyberbullying. Therefore, and since it is indicative that emotions originate from the brain, it will be worthwhile to see how the brain reacts toward cyberbullying as a stimulus. However, we are thankful for the development of neuroimaging devices like electroencephalography (EEG), functional magnetic resonance imaging or functional MRI (fMRI), which have made studying the complexity of these brain activities possible.

The current study focuses on identifying EEG signatures associated with emotional responses to cyberbullying. To approach this topic, a background on the aspect of cyberbullying was conducted to help in building a framework to approach the main research question. Meanwhile, it is important to consider that cyberbullying could have many forms (e.g., verbal harassment, name-calling, rumors, exclusion, etc.). Studying these forms independently enhances our understanding of how the brain might respond to them accordingly. Researchers like Willard (2011b) and Hinduja and Patchin (2007) pointed out that cyberbullying attacks take various forms and the worst of them all is the unlimited accessibility of the target which creates the greatest risk among them all. However, this accessibility is made possible by the advancement of social technology devices (e.g., smartphones), which classifies it as an extreme aggression attack that should be studied extensively with a multidisciplinary approach.

There is a large base of knowledge that discusses this problem using self-report measurements; studies using EEG measurement is rare. However, one of the self-reported studies indicated that publicity type has a different effect on the cyberbullying target (Slonje & Smith, 2008). This point is a candidate for our investigation in this study.

Therefore, the emergence of developing new patterns and forms to make the social media psychologically safer to use is of great importance to alleviate this social risk. The approach here should spark and direct social, psychological and computing studies toward understanding the problem using EEG.

1.2 Statement of The Problem

A very limited number of studies considered the aspect of cyberbullying through neurological activities. Some studies took cyberbullying from social exclusion side while others looked at from verbal harassment side. According to (Willard, 2011a) cyberbullying can take many different forms (e.g., flaming, harassment, cyberstalking, exclusion, denigration, impersonation, outing, trickery). Cyberbullying is also negatively impacted human well-being, and the necessity to study it from EEG angle is of great importance. Research on cyberbullying research in general is still in infancy stages, and more knowledge needs to be discovered (Völlink et al., 2015).

1.3 Significance and Contribution

A large number of works employed self-reporting methods to study the aspect of cyberbullying (Kowalski et al., 2008; Smith et al., 2008; Topcu et al., 2013; Willard, 2006). Rare studies have considered it from a neurological angle (Crowley et al., 2010; Kern, 2011; Otten et al., 2016). Those studies are of great importance to serve in EEG studies in relation to cyberbullying. However, it is important to emphasize that cyberbullying is not only exclusion but has different forms as well and human reactions toward each one of them could be different (Willard, 2006). To our knowledge, no study has made a comparison between the two main forms of cyberbullying using EEG.

1.4 Assumptions

For the purpose of this dissertation, cyberbullying will be studied using social exclusion and verbal harassment forms. Those forms might induce negative emotions on the individual who are cyberbullied. The preferred definition used for cyberbullying is "*willful and repeated harm inflicted through the medium of electronic text*" (Patchin & Hinduja, 2006). However, all subjects in this study are considered healthy right-handed individuals. Since Najarian and Splinter (2005) indicated that the brainwave for fourteen-year-olds is similar to adults. Thus, participants, aged 18–20, were a valid representative of this age range.

1.5 Research Objective

The main objective is to identify EEG signatures associated with the emotional responses and stress due to cyberbullying. To our knowledge, rare EEG studies have been done to explore publicity in cyberbullying. The overarching goal of this work is to develop a baseline that can be considered in future applications. This covers two objectives: to create a paradigm shift in understanding cyberbullying reactions through neural activities and to gain insights into the requirements to promote EEG as a tool for detecting cyberbullying. Attaining these goals would help in alleviating the negative effects of cyberbullying. Therefore, the purpose of the current research is primarily to measure EEG signatures associated with emotional responses and stress due to cyberbullying and secondarily to investigate the effect of different cyberbullying forms on EEG signatures.

1.6 Research Questions

The direction taken in this dissertation is driven by the observation that the issue of cyberbullying has been relatively under-investigated from a neurological perspective, specifically in the area of EEG. The popularity of social media is increasing the risk of cyberbullying that influences negative activities, which in turn affect human psychological safety.

Therefore, the following are the main research questions raised to approach the research problem by identifying EEG signature associated with emotional responses and stress to cyberbullying.

1. What are the effects of cyberbullying through social exclusion and verbal harassment on emotional, stress and neurological responses?
2. Does cyberbullying publicity influence emotional, stress and neurological responses?
3. Is there a correlation due to cyberbullying between emotional, stress responses and EEG signatures?

CHAPTER 2: REVIEW OF THE RELATED LITERATURE

This chapter sheds light on understanding the effect of cyberbullying using an electrophysiological measurement, specifically Electroencephalography (EEG). It reviews the existing state of knowledge in connection with cyberbullying. It starts with discussing the categories of cyberbullying to magnify and focus our research area of interest. Then it moves into details about EEG as a signaling tool and relevant behavioral aspects including emotions and stress. Previous EEG studies in connection with emotions, stress, aggression, and language, are reviewed to derive the study objective. In practice, studying EEG's signals can take two forms, time or frequency. Both domains are reviewed briefly to acquire the necessary background relative to the study.

2.1 Introduction

Bullying research has focused on underage bullying, workplace bullying (Farley et al., 2015; Gardner et al., 2016), burnout (Jaworek et al., 2010), mobbing (Yesilbas & Wan, 2017) and, most recently, cyberbullying. Bullying, in general, became a subject of research because of its harmful effects on human well-being. Individuals who are bullied might suffer from depression or lower self-esteem or, worst of all, may attempt suicide (Nansel et al., 2004).

The increased use of social media among all age groups in today's world has made it necessary to explore bullying in cyberspace from a different perspective, particularly among youth. Unlike previous generations, most youth today own smartphones and have grown up with the Internet. Thus, whether positive or negative, Internet use is undeniably a part of their daily life.

Cyberbullying statistics show that one-fifth of teens have experienced cyberbullying sometime in their lives (Hinduja & Patchin, 2010b). According to research by the Crimes Against Children Research Center (CACRC), the number of cyberbullying acts among teens increased from 6% to 11% between 2000 and 2010 (Jones et al., 2013).

Cyberbullying received significant attention from Canadian Centre for Occupational Health and Safety (CCOHS) because of the increasing incidents of verbal and non-verbal aggressive acts in social media and the considerable risk associated with (CCOHS, 2014). It has had negative emotional and physical impacts on people and has been cited as a contributing factor to many attempted suicides (Elgar et al., 2014). Cyberbullying attacks take various forms, but the greatest consequence has been the unlimited access to the target (Hinduja & Patchin, 2007; Willard, 2011b).

Researchers have used different experimental models to study cyberbullying. These include cyberball (e.g., cyberball (Williams & Jarvis, 2006), chat-rooms (Cohen & Prinstein, 2006; Kern, 2011; Wendi et al., 2000; Whitaker, 2014; Williams, Cheung, et al., 2000), role-playing (Kassner et al., 2012) and online-ostracism paradigm (Wolf et al., 2015)). Wolf et al. (2015) compared the computerized cyberball and an online-ostracism paradigm and concluded that both were effective and easy to use and provided a valid measure of social exclusion. Players interacting in a virtual environment via role-playing games may exhibit negative affect equivalent to those in real life (Kassner et al., 2012).

Although studies have used different techniques to elicit responses to cyberbullying, they relied solely on self-reported measures. This review presents the latest research and findings with respect to emotional responses and stress caused by cyberbullying. This integration of knowledge will promote efforts to prevent and detect cyberbullying. This literature review was conducted using published works combining the terms cyberbullying, bullying, emotions, stress and coping.

In the beginning, it was not conceived that the advent of communication technologies (i.e., Internet and smartphones) at the beginning of this millennium would help ruin people's lives. While the Internet is an indispensable asset that has transformed real human collaboration, this transformation has inherited real-world problems. One of those problems is bullying which is restated as "cyberbullying" to indicate that it takes place in the virtual space (Hinduja & Patchin, 2010b).

2.2 Cyberbullying Definition

"Cyberbullying" or "Internet harassment" is defined by the Canadian Center for Occupational Health and Safety (CCOHS) as "the use of the Internet to harass, threaten, or maliciously embarrass" (CCOHS, 2014). Researchers and government regulators disagree on how to define and characterize cyberbullying. Willard (2011b) suggested the term, "Digital Aggression" (Servance, 2003). The National Conference of State Legislatures (NCSL) differentiate cyberharassment from cyberbullying based on the cyberbullied individual's age as cited in (Hazelwood & Koon-Magnin, 2013; Scott et al., 2010).

Cyberstalking is an alternative term used to describe "the repeated pursuit of an individual using electronic or Internet-capable devices" (Bradford et al., 2011). Patchin and Hinduja (2006) defined it as "willful and repeated harm inflicted through the medium of electronic text." Even though the definition of cyberbullying seems similar to that of traditional bullying, the cyberbully's actions actually are more severe because of his or her unlimited access to the target and a larger audience (Berger, 2007; Johnson, 2009; Servance, 2003; Slonje & Smith, 2008; Sticca & Perren, 2013). Despite this difference, most of the literature uses the term cyberbullying (Farley et al., 2015).

Little is known about the negative effects of cyberbullying as compared to traditional bullying in the workplace. According to a study by Gardner et al. (2016), 2.8% of the population reported being cyberbullied in the six months before the study. They also indicated that most of the cyberbullied employees were in managerial positions. In their study, both cyberbullying and workplace bullying negatively impacted the target's emotional responses, which in turn reflected poorly in their work performance and increased their susceptibility to stress.

Cyberbullying is considered a part of so-called "social vulnerability" (Jawaid et al., 2012; Llorent et al., 2016). Social vulnerability is defined as "the disadvantage faced by somebody while s/he endeavors to survive as a productive member of the society" (Jawaid et al., 2012). Both cyberbullying and bullying are described as "aggressive conducts whose objective is to harm another person, which most certainly refers to violent social behavior" (Navarro et al., 2015). As cited in Kowalski et al. (2014), there are four forms of cyberbullying attacks: social, relational, physical and psychological (Dooley et al., 2012). Bullying can be classified as direct, “face-to-face” contact, and as indirect attacks where the “bullied target is not present” (Berger, 2007).

Cyberbullying may leave the targeted individual with lower self-esteem, depression, sadness, loneliness, suicidal thoughts (Willard, 2011b) or social dysfunction (Servance, 2003). Cyberbullying could create feelings of worry, terror, fear, depression, shame, exclusion and nervousness under the weight of never-ending threats (Hazelwood & Koon-Magnin, 2013). Attacks can take the form of playing a joke on someone, teasing the target, making mean, rude, threatening or aggressive remarks, or spreading hurtful rumors and lies (Johnson, 2009).

However, there was a debate of whether bullying is a form of aggression or not. Berger (2007) as cited in Gendreau and Archer (2005) indicated that “*not all aggression is bullying, but bullying is always aggression, presented as hurtful and hostile behavior*.” Cyberbullying is classified as “*indirect or relational aggression”* because it damages the target’s social relationships (Johnson, 2009).

Further and because of the anonymity in the cyber-world, cyberbullying target can be “introvert, extrovert, popular, famous, physically strong or weak” (Nowosad et al., 2011; Slaninova et al., 2011). Cyberbullying is accounted as a crime that leads to a feeling of fear, stress or anxiety on the cyberbullying target. It is a repetitive action which leads the target to live in fear and not know when the cyberbully will appear again (Hazelwood & Koon-Magnin, 2013).

2.3 Types of Cyberbullying

Further, cyberbullying can take many forms and characteristics. Eight common types of cyberbullying (see figure 1) include: (1) Exclusion—when a group of subjects blocks or isolates an individual from his or her social group or chat room; (2) Harassment—sending verbally rude and offensive messages to someone continuously; (3) Flaming—offensive arguments posted online between two or more aggressive users; (4) Cyberstalking—sending threatening messages or repeatedly spying or following a person so as to make him or her feel unsafe; (5) Denigration—posting online rumors to hurt an individual's reputation; (6) Impersonation—creating a fake profile online to make the targeted individual appear as someone else for the purpose of destroying his or her dignity or putting him or her at risk; (7) Outing—sharing personal or confidential information online without disclosed permission; and (8) Trickery—deceiving someone into revealing confidential or embarrassing information for the purpose of sharing it online (Willard, 2006).

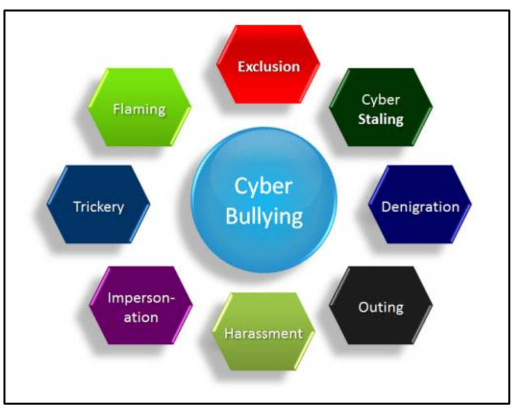

Figure 1. Cyberbullying types as classified by Willard (2006)

2.3.1 Social Exclusion

Social exclusion can take place in public or private (e.g., silent treatment). It is common across different cultures and age groups (Williams, Cheung, et al., 2000). It was reported to violate “the need-threat theory” (Baumeister & Leary, 1995). The theory described four elements as basic human needs (belonging, self-esteem, control, and meaningful existence (van Beest & Williams, 2006; Williams, 1997; Williams & Jarvis, 2006). Cyberbullied individuals score lower recognition after being socially excluded compared to non-cyberbullied individuals (Ruggieri et al., 2013).

Eisenberger (2006) pointed out that social inclusion is “pre-wired in our brain” and whenever an incident of social exclusion is triggered it leads to “social pain.” It was theorized that the brain is wired to detect exclusion (Kern, 2011). The brain senses exclusion and sends an alarm similar to the physical pain alarm except that the reaction is not wired but acquired through experience and personality (Williams, 2007). Williams et al. (2002) conducted an experiment called “cyber-ostracism” where they developed a simulated chat-room to manipulate social exclusion. Their self-report study concluded that cyber-ostracized subjects reported negative emotional impacts by the end of the experiment. This indicates that cyberbullying triggers emotions.

2.3.2 Verbal Harassment

Verbal harassment, in the context of this study, is text-based bullying that takes place during electronic social interactions. It is the most common form of bullying (Karwoski & Summers, 2016). Individuals bullied via both texting and traditional bullying were more depressed than those who faced traditional bullying only (Raskauskas, 2009). Willard (2011) indicated that the "Harassment" type produces incidents similar to those that occur in direct bullying.

Deficits in executive functioning were found to be correlated with bullying behavior for youth who engaged in antisocial and aggressive behaviors (Coolidge et al., 2004). Otten et al. (2016) inspected how the brain reacts against humiliation and what happened if this humiliation is accompanied with a laugh in public using ERP. Their experimental paradigm relies on presenting sentences in a sequence of word-by-word according to a time-stamped methodology known as Variable Serial Visual Presentation (VSVP) (Van Berkum et al., 2007).

2.4 Theoretical Background

Social Information Processing states that "Computer Mediated Communication (CMC) users can use the virtual medium to develop social interactions similar to the face-to-face interactions" Kleinginna and Kleinginna (1981). This indicates the nonverbal cues of the face-to-face have another alternative form (e.g., time) in CMC. This section discusses the theoretical background relevant to cyberbullying in terms of emotional and stress responses.

2.4.1 Emotional Responses

Although joy, sadness, happiness, and anger are just some of the emotions intuitively recognized by people, the definition of emotion until recently was subject to debate. Kleinginna Jr and Kleinginna (1981) gathered and classified ninety-two proposed definitions of emotion and found little consensus in the literature. Despite the disagreement over the definition, "*researchers did agree on two aspects of emotion: (1) Emotion is a natural reaction to an event related to the goals, needs and concerns of an individual; and (2) emotion involves affective, behavioral, physiological and cognitive components*" (Brave & Nass, 2003).

Many theories of emotion have attempted to describe the sequence of responses to a given stimulus. For example, the James-Lang theory held that emotions were caused by physiological arousal triggered by the emotional stimulus (Myers, 2004). The Cannon-Bard theory (Cannon & Britton, 1925) stated: "*Emotional stimulus simultaneously triggers physiological response and the experience of emotions*" (Myers, 2004).

In literature, Emotion theories have been divided into two categories to classify and distinguish emotions properly. Discrete emotion theories suggested the use of basic main emotion from which all secondary emotions can be derived (Garcia-Molina et al., 2013). Other theories classify emotions on a dimensional basis. For example, Watson and Clark (1984) created the positive affect–negative affect model (PANA). PANA separates negative and positive affect into two different systems, where the vertical axis represents positive affect, and the horizontal axis represents negative affect.

Even though the acronym PANA might suggest measuring emotions as an opposite affective state (e.g., positive affect should possess a strong negative correlation with negative affect), they are two different dimensions. Positive affect depicts the degree to which an individual feels active, enthusiastic and alert. A high level of positive affect indicates enjoyable engagement. Negative affect, in contrast, is generally correlated with subjective distress and unpleasant engagement, both of which reflect aversive states, such as anger, guilt, nervousness or disgust. The lower level of negative affect produces a state of serenity and calmness (Watson & Clark, 1984; Watson et al., 1988).

In this study, the measurement of emotional responses is a function of both positive affect and negative affect dimensions. Thus, during cyberbullying or negative social interactions, it was expected to observe a lower level of positive affect and a higher level of negative affect (Gemzøe Mikkelsen & Einarsen, 2008; George, 1996).

According to Hinduja and Patchin (2010), Cyberbullying produces negative emotional impacts that vary based on the type of cyberbullying that the target experiences and his personal reactions to it (Ortega et al., 2012).

Many psychometric instruments have been constructed to assess emotions. One of the instruments that have been validated and cited in more than 21,900 published works is the Positive and Negative Affect Schedule (PANAS). Built on a PANA model, this is an instrument designed to measure the two aspects of emotions (negative and positive) (Watson et al., 1988).

2.4.2 Cyberbullying and Stress

According to the Conservation of Resources (COR) theory (Hobfoll, 1989), a person experiences stress when threatened with losing something that he or she values most, such as social interaction (Giumetti et al., 2013). Under this theory, a person maintains multiple resources, including objects, personal characteristics, social supports, conditions, and energies (Alvaro et al., 2010; Hobfoll, 2004). Cyberbullying can lead to stress because it threatens basic human needs, such as the need to belong (Williams & Carter-Sowell, 2009).

On the other hand, the transactional model of stress theory provides that an individual's appraisal of a stressful event is supported by how they cope with that event (Lazarus & Folkman, 1984). Thus, cyberbullying events have been shown to create stress for some people (Jang et al., 2014), and the transactional model of the stress theory has been used in much of the cyberbullying research (Völlink, Bolman Catherine, et al., 2013).

Repetitive stressors over time can induce emotional distress and, in turn, lead to decreased performance levels (Giumetti et al., 2013; Szalma & Hancock, 2011). On the other hand, social support can attenuate the negative impact of stressful events (Duffy et al., 2002; Mohr et al., 2010). Stress is perceived as a source of diminished performance (Hancock, 1989). Therefore, Therefore, cyberbullying induces immediate emotional responses (affects) and stressful responses (cognitive). Repetitive events of cyberbullying can cause not only immediate emotional responses but also persistent ones. Cyberbullying can thus have both chronic (long-term, longer-lasting) and acute (short-term) effects. Chronic stressors are those lasting longer and deviating from the short-term characteristics of an acute stressor (Smyth et al., 2013).

The Dundee Stress State Questionnaire (DSSQ) developed by Matthews et al. (1999) has been widely used in task-related experimental designs requiring assessment of the level of stress attributable to manipulated tasks. Matthews et al. (2013) linked stress state factors from the DSSQ to the Lazarus (Lazarus & Folkman, 1984) Transactional Model of stress. This theory characterized stress as the result of appraisal and all perspectives that support this view (Hobfoll, 2001). DSSQ assesses three forms of stressors: Task engagement, distress, and worry.

2.4.3 Coping with Cyberbullying

Coping is defined as the behavioral and cognitive capabilities an individual deploys to tolerate and control stressful events (Lazarus & Folkman, 1984). According to the Lazarus transactional theory, two types of cognitive appraisals—judgment and evaluation—are associated with coping demands. Both types reportedly provide valid predictors of coping (Aldwin, 2007; Mariana et al., 2014).

Sources of stressors and their related coping strategies vary significantly among individual human characteristics and differences (Lazarus, 1991). People who employ problem-focused coping tend to be less affected by stressful events than those who use emotion-focused coping (Lazarus Richard & Folkman, 1987). In the context of cyberbullying, the problem-solving strategy is far better than reacting to avoid or deny the problem (Völlink, Bolman, et al., 2013). Emotion-focused coping toward cyberbullying has been found to be highly associated with health complaints (Völlink, Bolman, et al., 2013). Female teenagers who tended to use avoidance strategies were observed to possess lower self-esteem (Lodge & Frydenberg, 2007).

An appraisal is the self-perception of an attack and the evaluation of how to use available resources to face a threat (Raskauskas & Huynh, 2015). This can take many forms, including threats to self, threats of harm and threats of loss (Mariana et al., 2014). In general, the selected coping strategy is based on individualistic differences and the personal capability to appraise each threat differently.

2.5 Cyberbullying Factors

What makes cyberbullying different from bullying, in general, is publicity and anonymity: The potential of reaching a large audience and doing so anonymously (Slonje & Smith, 2008; Sticca & Perren, 2013).

2.5.1 Publicity

Publicity has been described as the number of audiences communicating in social media either privately (e.g., one-to-one) or publicly (many-to-many) (Sticca & Perren, 2013). Cyberbullying publicity can be either private (e.g., email) or public (e.g., Twitter or a public website) (Sticca & Perren, 2013). Publicity has been considered a factor of cyberbullying (Dooley et al., 2009). Prior studies found that public cyberbullying to be more stressful than private (Pieschl et al., 2015; Sticca & Perren, 2013). Smith et al. (2008) hypothesized that "as the number of people participating online increases, the severity of cyberbullying increases." On the other hand, a different experimental study concluded that publicity was not a relevant factor in cyberbullying (Menesini et al., 2012).

Subjective measures indicated that cyberbullying was more destructive in a public form than in private (Sticca & Perren, 2013). This was in agreement with the findings of Slonje and Smith (2008) and Smith et al. (2008) in proving that publicity ranked higher than the medium it uses (e.g., traditional bullying vs. cyberbullying). This study offers further evidence of the important role that publicity plays in cyberbullying (Otten et al., 2016). According to a self-report study conducted by Vasquez et al. (2013), verbal harassment triggers more emotional impact in public than in private. This was attributed to the “larger emotional processing” triggered in public, which in turn increases brain activity (Otten et al., 2016).

A key aspect of private cyberbullying is the so-called “silent treatment”—a “relational aggression” from a partner (Williams, Cheung, et al., 2000; Young et al., 2010). This is viewed as a form of social exclusion, where the target is ignored and rejected (e.g., sending repeated text messages to another and not receiving any in return) (Williams, 2007). Out of 2,000 Americans surveyed, 75% reported having experienced “silent treatment” from their partners (Faulkner et al., 1997). This reflects the popularity of this private angle in social exclusion.

2.5.2 Anonymity

Anonymity as a factor of cyberbullying has received the least amount of attention in cyberbullying research (Sticca & Perren, 2013). Qualitative studies have shown that anonymity induces a higher level of distress if the individual who was cyberbullied suspected or perceived that the attack came from people around him or her, including friends or schoolmates (Mishna et al., 2009). Anonymous cyberbullying communication can be less severe if it is perceived as misaddressed or sent randomly as a hoax (Slonje & Smith, 2008; Sticca & Perren, 2013). Being cyberbullied by someone known was found more distressing than if the source had been unknown (Nocentini et al., 2012).

2.6 Electroencephalogram (EEG)

Measurement of the brain electrical activities is one of the unique approaches to understand human information processing. Electroencephalogram (EEG) measures the brain scalp activities via electrodes in microvolts. EEG was also further extended to allow humans to interact with machines via Brain-Computer Interfaces (BCI). Luck and Kappenman (2013) pointed out that researchers had found a relationship between the brain's activities and how humans react toward a given stimulus. For example, the neural signals associated with happiness, sleeping or thinking stem from the brain. To understand this neural processing, researchers have indicated the importance of dividing the brain into two parts (Right and Left). Right-handed people have their primary activities processed on the left side of the brain (Nielsen et al., 2013; Stephan et al., 2003). Nielsen et al. (2013) pointed out that the two regions have two special neural signatures: the left area has an association with language while the right region is associated with attention.

Since the EEG measures data from the scalp, some studies divided the cortex into four lobes (frontal, occipital, parietal, and temporal). Each of the lobes has different functions. The frontal lobe is related to thinking, planning, movement, problem solving and emotions. Visual processing is conducted in the occipital lobe. Parietal oversees body movement, recognition, and perception. The temporal lobe is related to memory, hearing, and speech (Kinser & Grobstein, 2000). Brain activities produce different voltage levels. Habash (2007) indicated that EEG amplitude is almost ±100 µV when measured on the scalp which is actually less than the actual brain voltage of ±2 mV. Accordingly, Crowley et al. (2010) mentioned that, since this electrical activity stems from the brain, it will provide an indispensable and unique understanding of brain responses toward stimulus.

EEG Emotion-related signals have been widely investigated since the 90s using power spectral analysis and event-related potential methods (Yoon & Chung, 2011). These methods provide the capability to quantify and analyze brain activity during social interaction. The next section discusses those two methodologies in greater depth.

2.6.1 EEG Frequency Bands

The scalp receives neural activity at many different frequencies as electrical waves. They are classified into ranges of EEG frequency bands known as delta, theta, alpha, beta, and gamma. EEG signal is usually classified in terms of frequency, amplitude, and scalp region (Brazier et al.; Noachtar et al., 1999). Changes in frequency bands' amplitude serve as a coder to understand how the brain responds to mental tasks (see Table 1).

Table 1. Mental states associated with EEG frequency bands

EEG Band	Range	Mental association
Delta (δ)	(1–4 Hz)	Deep sleep.
Theta (θ)	(4–8 Hz)	Inattentiveness, meditation, and emotional processing
Alpha (α)	(8–13 Hz):	Mental and physical relaxation and positive emotions, physical improvement, Improved memory.
Beta (β)	(13– 30 Hz)	Relaxed focus, anxiety, alertness, stress, confusion, vigilance and concentration and analytical thinking" (Demos, 2005)
Gamma (γ)	(>30 Hz)	Learning, high concentration, and meditation" (Blanchard et al., 2007).

2.6.2 Power Spectral Density (PSD)

PSD is a frequency domain measurement of the signal strength. It illustrates the power distribution at different frequency bands in EEG time series (Fadzal et al., 2014). Although EEG Emotion-related signaling has been widely investigated since the 90s using power spectral analysis and ERP methods, PSD method is more common for emotional studies (Yoon & Chung, 2011).

The EEG amplitude fluctuates randomly and rapidly over time. This randomness can be represented using the PSD methods by plotting power against frequency. This transformation is conducted using a process called Fast Fourier Transform (FFT) to represent the signal as a spectrum which is the frequency content of a signal (Proakis & Manolakis, 1996). There are many methods used to estimate PSD. One of the most used methods is PSD Welch (Welch, 1967). Some studies have proven that the Welch method (a.k.a periodogram method) (Welch, 1967) provides a more accurate representation of EEG features to reduce the variance (Fadzal et al., 2014). An example of a single subject PSD is depicted in figure 2.

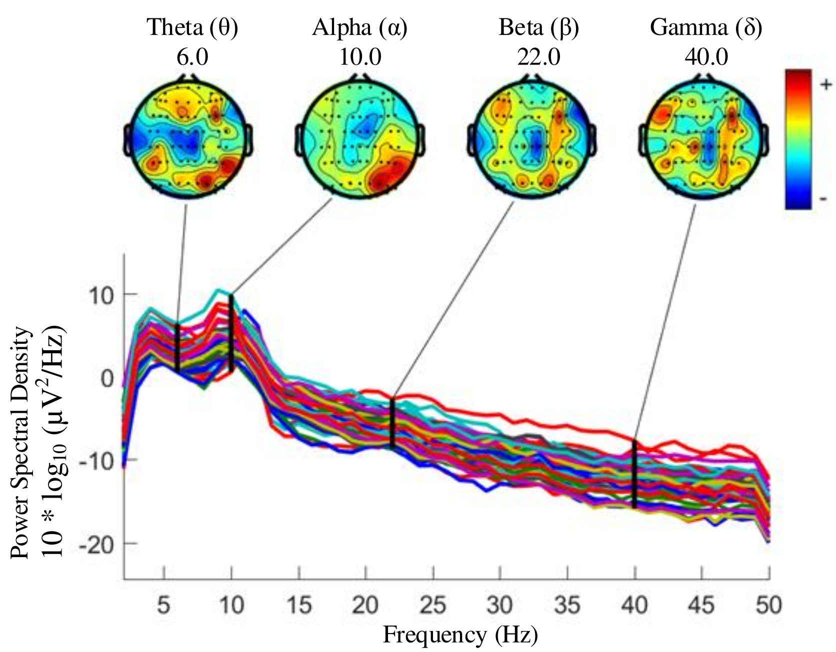

Figure 2. An example of one subject Power Spectral Density (PSD) plot

Power spectral analysis was used in many research works to study the association between emotional states and EEG. Kostyunina and Kulikov (1996) demonstrated that the power spectrum peak for alpha increases with anger and joy while it decreases with fear. Further, Klimesch (1999)and Ray and Cole (1985) found that the alpha band is related to cognition while the beta band is related to emotions. Li and Lu (2009) indicated that the gamma band is useful for emotional classification. Zheng and Lu (2015) found a relationship between emotions and neural signature and noticed an increase in beta and gamma power for positive emotions while it is lower for negative emotions. Yoon and Chung (2011) showed that there is a relationship between alpha, beta, and gamma and the experienced level of emotions. They demonstrated that gamma is associated with anxiety while alpha was triggered high during joy and triggered low during fear and sadness. Greater theta power in the left frontal brain region during sadness compared to happiness was reported (Costa et al., 2006).

DeLaRosa et al. (2014) observed that threatening stimulus evokes an increase in theta activity in the occipital lobe followed by an increase of theta power in the frontal lobe. Papousek and Schulter (2002) noticed differences in frontal alpha power in response to positive and negative emotions. The alpha power wave of the left sphere decreases with positive emotions while it decreases in the right sphere with negative emotions (Yoon & Chung, 2011). Based on this assumption, standard EEG frequency bands were investigated in this study.

2.6.3 Event-Related Potential (ERP)

An ERP is a sequence of peaks which appear in the EEG in response to a specific stimulus in a time-locked manner (Rosenfeld, 2002). The ERP is represented by a set of positive or negative peaks called “ERP components.” Each of the ERP components is represented by its timing, polarity, and scalp distribution (Barry et al., 2003; Hajcak et al., 2010; Woodman, 2010).

One of the potentials of ERP components is its ability to provide “temporal resolution” in milliseconds (Luck, 2014). It plays an important role in exploring the human mental process as ERP represents neural activity in response to cognitive and perceptual acts. For example, early peak represents sensory processing while late peak represents cognition (Hillyard & Kutas, 1983).

ERP techniques can provide an accurate temporal representation of the neural events in relation to cyberbullying responses. This temporal resolution is an ideal candidate for research question to extract the sequence of ERP components involved in mental processing (Bartholow & Dickter, 2007). Recent claims indicated that ERP could provide an acceptable spatial resolution, and Luck (2014) recommended that such claims should cautiously be tested. The uniqueness of ERPs to the study of psychological processes is the association of individual ERP components with similar information processing operations (Gehring et al., 1992; Ito, 2011). The amplitude of the components represents the degree of psychological response while the peak latency represents the point where it has been completed (Ito, 2011).

Typically, it is emphasized that earlier components (e.g., N1) describe the attentional processing and sensory information while the later components (N2 and following components) are more reflective of cognitive information processing (Bartholow & Dickter, 2007; Polich, 2007). Traditionally, most of the social cognition studies have concentrated on later ERP components (Bartholow & Dickter, 2007).

2.6.3.1 ERP Emotion-Related Components

Emotion is generated in the brain, and it is associated with the brain's cognitive information process. Thus, EEG is an indispensable measure in distinguishing emotions (Yoon & Chung, 2011). ERP components have been studied under the emotional umbrella (Hidalgo-Muñoz et al., 2013). Research conducted by Carretié et al. (2001) and Olofsson et al. (2008) groups indicated that P2, N2, P3 components are related to emotions.

2.6.3.2 Late Positivity Potential (LPP)

There are two temporal stages in reaction to the exposed emotional stimulus, time from onset to the peak and post-peak time (a.k.a recovery time) (Daren et al., 2003). This is supported by research in neurosciences showing that the post-recovery time and duration vary in healthy samples (Daren et al., 2003). This temporal response has been evaluated via timed-locked ERPs.

Many ERP components that have been studied are about emotional responses. One of the most widely used components is Late Positive Potential (LPP). A study of Hajcak and Olvet (2008) pointed out that negative emotions sustained after stimulus offset to at least 1s. It has a peak amplitude around the central electrode CPz between 300ms and 650ms (Hajcak et al., 2010; Hajcak & Olvet, 2008; Schupp et al., 2004). It is relevant to the stimulus-affective processing (Hajcak et al., 2012).

LPP can be induced with positive or negative emotional words and sentences (Herbert et al., 2008; Otten et al., 2016). However, (Ibáñez et al., 2009)reported that LPP is a part of a group of different ERP components rather than what was initially considered by Sutton et al. (1965) as "unique frontal, bilateral positivity" component. Its amplitude increases to threatening and negative stimuli rather than positive stimuli (Briggs & Martin, 2009; Hajcak et al., 2012; Schupp et al., 2004). Humiliation triggers to negative emotion (Otten et al., 2016). Thus, cyberbullying could trigger the LPP component with larger amplitude. According to van Berkum (2009), sentences that morally violate personal values are considered emotionally unpleasant. It will evoke a larger LPP than neutral words (van Berkum, 2009). As part of social exclusion studies, LPP was also triggered by Crowley et al. (2010). For example, during the cyber-ball experiment, the individual who is cyberbullied was observed to trigger an ERP component localized at the Left-frontal similar to LPP between 580ms and 900ms post-stimulus (Crowley et al., 2010). ERP is stated to have gender differences related to the processing of negative emotions (Gasbarri et al., 2006; Kemp et al., 2004). However, not all research indicated the existence of gender differences (Rozenkrants et al., 2008). LPP, during the emotional process, is evoked by "violating index expectancy" and can be counted as a unique case of the P300 (Cacioppo et al., 1994; Yakub, 2013). However, Foti et al. (2009) indicated that there could be an overlap between the two components around 300ms to 500ms time window. In their research, they deployed Principal Components Analysis (PCA) and found that the P300 peaks around 350ms in occipital and parietal regions. The LPP peaks (>600ms) appear at (occipital to central) areas (Kujawa et al., 2013). In all, P300 peaks earlier and is related to attention while LPP peaks later and represents emotional processing (Kujawa et al., 2013; Lauren Kennedy, 2014; Nechvatal & Lyons, 2013). LPP represents unique components that affect emotions (Foti et al., 2009).

2.6.3.3 N100 Component

N100 Component peaks at 100ms after auditory stimulus onset followed by P200, which peaks around 175ms (Tremblay et al., 2001). N100 was assumed initially to be triggered in response to auditory stimulus (Näätänen & Picton, 2007). However, it was also noticed during visual stimulus experiments (Luck, 2014). Posner and Petersen (1990) and Petersen and Posner (2012) found that the frontal area is involved with target detection, while the posterior area is related to visual processing. A meta-analysis by Ibanez et al. (2012) noticed that N100 and P100 could be associated with emotions. This might confirm that the processing of emotion starts in earlier stages (Schapkin et al., 2000).

2.6.3.4 N200 Component

N200 is a negative component occurring at 200ms-400ms after stimulus onset had been correlated to incorrect responses (Kopp et al., 2007; Yeung et al., 2004). In a social exclusion study, N200 had been hypothesized to elicit larger amplitude when the subject experienced exclusion (Khatcherian, 2011).

2.6.3.5 N400 Component

Kutas and Hillyard (1980) discovered N400 components in 1980 as a component related to linguistics stimuli, but recently it is involved in nonlinguistic studies (Hillyard & Kutas, 1983; Kutas & Hillyard, 1980). The N400 goes onset around 150 to 250 ms and peaks between 380 and 440 ms post-stimulus (Kappenman & Luck, 2011; Swaab et al., 2012). It might cover the central parietal region (Kutas & Federmeier, 2010; Swaab et al., 2012; van Berkum, 2009; Van

Berkum et al., 2007). It can be evoked via unexpected phrases or words. Larger N400 amplitude was noticed in a sequence of surprising words (Hillyard & Kutas, 1983). Kutas and Federmeier (2010) indicated that it is now more related to the processing of meanings. Wabnitz et al. (2012) observed that N400 amplitude is larger for socially threatening words than neutral words. Otten et al. (2016) interpreted that it occurs because degrading words violate the "syntax structure." van Berkum (2009) noticed that words that violate personal values or have emotional meanings would raise N400 amplitude.

2.6.3.6 P300 Component

The P300, peaking around 200-500ms after stimulus onset, was first reported by Sutton et al. (1965). It is one of the widely researched components and appears initially as related to motivational stimuli and attention (Kappenman & Luck, 2011). P300 Peaks at central and parietal areas against surprising condition (Donchin et al., 1978). P300 components' activities increase in the left hemisphere against emotional stimuli (Schapkin et al., 2000). According to a phobic spider study by (Schienle et al., 2008), P300 and LPP amplitudes were larger with the phobic stimuli. Further, many studies have proven that the emotional stimulus is able to induce the P300 components (Schupp et al., 2004). P300 amplitude and scalp distribution are different between the deceptive and the true state (Rosenfeld et al., 1998).

2.7 Experimental Approaches to Cyberbullying

Different experimental models were used to study cyberbullying in the lab (e.g., cyberball (Williams & Jarvis, 2006), chat-rooms (Cohen & Prinstein, 2006; Kern, 2011; Wendi et al., 2000; Whitaker, 2014; Williams, Cheung, et al., 2000), role-playing (Kassner et al., 2012) and online-ostracism paradigm (Wolf et al., 2015)). Wolf et al. (2015) compared the computerized cyberball and an online-ostracism paradigm and concluded that both were effective and easy to use and provided a valid measure of social exclusion.

2.8 Prior relevant studies

There is an increasing number of studies employing self-report methods to study an aspect of cyberbullying (Kowalski et al., 2008; Smith et al., 2008; Topcu et al., 2013; Willard, 2006)but only a few studies have considered it implicitly from a neurological angle (Crowley et al., 2010; Kern, 2011; Otten et al., 2016). However, Google Scholar and Pubmed databases show that no previous EEG study focused on explicitly studying different types of cyberbullying. Nevertheless, previous studies are strongly and relatively related to approaching cyberbullying research using EEG (see table 2).

Williams et al. (2002) conducted an experiment called "cyber-ostracism," where they developed a simulated chat-room to manipulate social exclusion. Their self-report study concluded that cyber-ostracized volunteers stated negative emotional impacts by the end of the experiment. This indicates that cyberbullying might trigger emotions.

Crowley et al. (2010) used a cyberball paradigm to report that young adults experiencing exclusion had P300 and LPP slow waves. Using the same paradigm, Khatcherian (2011) found larger N200 and smaller P300 components during the exclusion phase.

Previous social exclusion studies demonstrated that decrease in frontal theta could be a marker for social exclusion (Cristofori et al., 2012; van Noordt et al., 2015; Wang et al., 2017).

Thus, socially negative interactions were predicted to present an increase in theta EEG power at the frontal brain region in comparison to socially positive interactions. Moreover, Yoon and Chung (2011) showed a relationship exists between theta, alpha, beta, and gamma and the experienced level of emotions. They demonstrated that gamma is associated with anxiety while alpha was triggered high during joy and triggered low during fear and sadness. Based on this assumption, the standard frequency bands (theta, alpha, beta, and gamma) was studied independently. Thus, socially negative interactions were predicted to present significant differences of EEG power to socially positive interactions at each of the standard frequency bands. This investigation was also extended by dividing the brain cortex into five spatial regions (left anterior, right anterior, left posterior, right posterior, and midline). Moreover, it is predicted that cyberbullying in public would induce different EEG activities compared to cyberbullying in private form.

Otten et al. (2016) inspected how the brain reacts against humiliation and what happens if this humiliation is accompanied with laughter in public. They reported that humiliation induces larger N400 and LPP amplitudes in general. However, if it is accompanied by a laugh, N400 amplitude decreases while LPP amplitude increases. Their experimental paradigm relies on presenting each sentence in a sequence of word-by-word according to a time-stamped methodology known as Variable Serial Visual Presentation (VSVP) (Van Berkum et al., 2007).

DeLaRosa et al. (2014) pointed out that increase in occipital theta activity followed by an increase of frontal theta power due to displaying threatening stimulus. Changes in frontal alpha power in response to positive and negative emotions were observed by Papousek and Schulter

(2002). Yoon and Chung (2011) reported that left alpha power decreases with positive emotions while on the right sphere it decreases with negative emotions.

Table 2. Cyberbullying relevant studies

Work	EEG Form	Study Area	Experimental Paradigm	Subjects
Sticca and Perren (2013)	-	Cyberbullying	Self-reported hypothetical cyberbullying scenarios	43
Giumetti et al. (2013)	-	Cyberbullying	Scenario-based	67
Otten and Jonas (2014)	N2, LPP	Humiliation	Scenario-based	40
Otten et al. (2016)	LPP, N400	Humiliation	(VSVP)	46
Khatcherian (2011)	N200, P300	Social exclusion	Cyberball	25
Whitaker (2014)	Theta power	Social exclusion	Chatroom	56
Kern (2011)	Theta power	Social exclusion	Cyberball	34
Williams et al. (2002)	-	Social exclusion	Chatroom	43
Otten and Jonas (2013)	N2, P3	Social exclusion	Scenario-based	46
Wendi et al. (2000)	-	Social exclusion	Computerized Chatroom	91
Crowley et al. (2010)	LPP, P300	Social exclusion	Cyberball	33
DeLaRosa et al. (2014)	Theta power	Visual Threat	Threating Picture	32

2.9 Current Study

Chapter one highlighted the motivation to inspect the problem of cyberbullying using a new angle. The literature review discussed in this chapter emphasized how EEG can prove itself as a valid measure to assess the problem. Analyzing EEG in the frequency band is important as brain activity behaves differently across different frequencies. The literature review revealed that this research problem could be studied in the context of emotions, stress and neurophysiological responses by relying on the previous studies in the area of (emotions, social exclusion, and aggression). In addition, this study explored if these neural activities can significantly have been influenced by cyberbullying publicity and social interactions. By relying on relevant self-reported studies, it was predicted that cyberbullying in public will elicit a different EEG signature. It is also expected that the cyberbullied target would experience more negative emotional and stressful impacts.

Publicity was reported to be a factor of cyberbullying (Dooley et al., 2009). Cyberbullying can take a private (e.g., email) or public (e.g., Twitter or public website) (Sticca & Perren, 2013). Previous studies by Pieschl et al. (2015) and Sticca and Perren (2013) have reported that public cyberbullying form is more distressing than the private one. On another experimental study by Menesini et al. (2012), publicity as a factor did not show relevance to cyberbullying. Thus, cyberbullying in public was predicted to induce more negative emotional reaction in comparison to private form as reflected by lower positive affect and higher negative affect.

Cyberbullying was predicted to present elevated negative stress responses in comparison to socially positive interactions as reflected by at least one of the following attributes (reduction in task engagement, an increase of distress and/or an increase of worry). It is also predicted that cyberbullying in public would induce more negative stressful reactions in comparison to private form as reflected by at least one of the following attributes (reduction in task engagement, an increase of distress and/or an increase of worry).

Cyberbullying through social exclusion were predicted to present a different level of coping strategies as reflected by (task focus, emotion-focus and/or increase avoidance) in comparison to socially positive interactions. It was also predicted that cyberbullying in public present different level of coping strategies as reflected by (task focus, emotion-focus and/or increase avoidance) in comparison to private form as reflected by at least one of the following attributes decreasing task focus, increasing emotion-focus and/or increase avoidance.

2.10 Summary

In this chapter, a background in the topics related to the proposed study is reviewed. It provided insight on building up the foundational framework to proceed with the study. After that, the discussion of EEG signature types was briefly discussed followed by the emotional responses due to cyberbullying that can be helpful in this study. Then, related EEG studies were reviewed to provide a background of the status of the relative knowledge. The review revealed that the magnitude and severity of cyberbullying on human integrity are higher than expected, and the necessity to study it using multidisciplinary approaches is of great importance. Finally, understanding the relationship between cyberbullying and EEG signatures is essential to make socio-technical systems psychologically safer. In turn, this will lead to a remarkable shift toward developing detection and prevention mechanisms.

CHAPTER 3: STUDY ONE "EFFECTS OF CYBERBULLYING THROUGH SOCIAL EXCLUSION ON EMOTIONAL, STRESS AND NEUROPHYSIOLOGICAL RESPONSES"

3.1 Introduction

Social exclusion can take place in public or private (e.g., silent treatment). It is common across different cultures and age groups (Williams, Bernieri, et al., 2000). It was reported to violate "the need-threat theory" (Baumeister & Leary, 1995)." The theory described four elements as basic human needs (belonging, self-esteem, control, and meaningful existence (van Beest & Williams, 2006; Williams, 1997; Williams & Jarvis, 2006). Cyberbullied individuals score lower recognition after being socially excluded compared to non-cyberbullied individuals (Ruggieri et al., 2013).

Eisenberger (2006) pointed out that social inclusion is "pre-wired in our brain" and whenever an incident of social exclusion is triggered it leads to "social pain." It was theorized that the brain is wired to detect exclusion (Kern, 2011). The brain senses exclusion and sends an alarm similar to the physical pain alarm except that the reaction is not wired but acquired through experience and personality (Williams, 2007). Williams et al. (2002) conducted an experiment called "cyber-ostracism" where they developed a simulated chat-room to manipulate social exclusion. Their self-report study concluded that cyber-ostracized subjects stated negative emotional impacts by the end of the experiment. This indicates that cyberbullying triggers emotions.

3.1.1 Objective

The objective of this study is to investigate the effect of cyberbullying through social exclusion on emotional, stress and neurophysiological responses. This research also examined how cyberbullying factors of social interaction and publicity affect the emotional and stress responses.

3.1.2 Subjects

Most of the behavioral studies require large sample sizes to obtain an adequate statistical power, but in the case of EEG studies, it is different. It can take a smaller sample size to achieve such equivalent statistical power (Hensel et al., 2017; Sands, 2009). There is no exact sample size for EEG research (Budzynski, 2009). However, if you have less number of trials you have to increase the number of subjects (Woodman, 2010).

Twenty-nine undergraduate students (16 females, 13 males; mean age 18.33) volunteered for the experiment via UCF's psychology research participation system (SONA). They were recruited between July 10, 2017, and August 20, 2017. In appreciation of their efforts, they had the option of either receive class credit according to the SONA system or receive monetary compensation of $30. Demographic data were summarized in table 3. However, the subject's selection was limited to healthy individuals, right-handed, native speakers of English, and had a normal or corrected-to-normal vision with no neurological disorder. Thus, subjects in this study claimed to be healthy individuals with no known neurological or psychological diseases, free from cardiac problems and had normal to corrected vision. Subjects were advised to be caffeine-free for at least 3 hours and alcohol-free for at least 24 hours. They had the choice to either get paid the amount of between of ($5-$30) in cash or receive class credit equivalent to maximum hours of participation according to SONA system. Recruitment of almost an equal number of male and female was performed to control any possible gender confound. They were informed they were free to withdraw from the experiment anytime they wish. There were two cases of where data was excluded from the analysis, if the subject withdrew from the experiment or if their EEG measurements had an excessive number of artifacts.

Table 3. Summary of subject's demographics and anthropometric characteristics

	Female = 16			Male= 13		
Variable	Mean	S.d	Range	Mean	S.d	Range
Age (years)	18.25	0.58	18-20	18.46	1.13	18-22
Weight (kg)	131.2	25.15	90-170	164.85	42.3	110-275
Height (cm)	161.45	5.24	155- 170	177	5.54	167-188

3.1.3 Experimental Design

Two-way repeated measures experimental design was selected with two levels of cyberbullying publicity and two levels of social interaction (see figure 3). The selection of the repeated measures was used because all subjects performed all interventions in random order.

Study 1: Social Exclusion				
Publicity	Public		Private	
Social Interaction	Social Exclusion	Social Inclusion	Social Exclusion	Social Inclusion

Figure 3. Social exclusion study: design of the experiment

3.1.4 Research Variables

The independent variables in this study were cyberbullying publicity and social interaction. Each of the independent variables has two levels. That is, cyberbullying publicity is private vs. public, social interactions (exclusion "negative" vs. inclusion "positive"). Description of each of the independent variables is summarized in table 4. The dependent variables were EEG power, emotional responses (positive affect and negative affect), stress (task engagement, distress, and worry) and coping (task-focus, emotion-focus, and avoidance).

Table 4. Social exclusion study independent variables description

Independent Variables	Level	Description
Cyberbullying publicity	Private	Social interaction is only limited between 2 people
	Public	Social interaction is in one group of 3 or more people
Social interaction	Social exclusion	The subject does not receive the ball fairly during the game
	Social inclusion	Subject receives the ball fairly during the game

3.1.5 Hypotheses

In all, the previous theoretical and literature arguments provided some indication to link EEG with emotional and stress responses to cyberbullying. Therefore, and based on the previous evidence, the current study's claim the following hypotheses:

Hypothesis 1: At least one of the factors (social interaction and publicity) influences emotional responses.

Socially negative interactions "social exclusion" were predicted to present elevated negative emotional reaction in comparison to socially positive interactions "social inclusion" as reflected by lower positive affect and higher negative affect. Publicity was reported to be a factor of cyberbullying (Dooley et al., 2009). Cyberbullying can take a private (e.g., email) or public (e.g., Twitter or public website) (Sticca & Perren, 2013). Previous studies by Pieschl et al. (2015) and (Sticca & Perren, 2013) have reported that public cyberbullying form is more distressing than the private one. On another experimental study by Menesini et al. (2012), publicity as a factor did not show relevance to cyberbullying. Thus, it is predicted that cyberbullying in public would induce a more negative emotional reaction in comparison to private form as reflected by lower positive affect and higher.

H_{1a} = There is a significant difference in emotions between the two social interaction levels (social exclusion and social inclusion)

H_{1b} = There is a significant difference in emotions between the two publicity levels (public and private)

Hypothesis 2: At least one of the factors (social interaction and publicity) influences stress responses.

Socially negative interactions "social exclusion" were predicted to present elevated stress reaction in comparison to socially positive interactions as reflected by at least one of the following attributes: decreasing task engagement, increasing distress and/or increased worry higher. It was also predicted that cyberbullying in public would induce a more negative stressful reaction in comparison with private form as reflected by at least one of the following attributes decreasing task engagement, increasing distress and/or increase worry higher as measured by DSSQ-3.

H_{2a} = There is a significant difference in the stress level between the two social interaction levels (social exclusion and social inclusion)

H_{2b} = There is a significant difference in the stress level between the two publicity levels (public and private).

Hypothesis 3: At least one of the study manipulation factors (social interaction and publicity) influences coping responses.

Socially negative interactions “social exclusion” were predicted to present elevated positive coping reactions in comparison to socially positive interactions “social inclusion” as reflected by at least one of the following attributes decreasing task focus, increasing emotion-focus and/or increased avoidance. It is also predicted that cyberbullying in public would induce more negative coping with stress responses in comparison to private form as reflected by at least one of the following attributes decreasing task focus, increasing emotion-focus and/or increased avoidance.

H_{3a} = There is a significant difference in coping with acute stress responses between the two social interaction factors (social exclusion and social inclusion)

H_{3b} = There is a significant difference in coping with acute stress responses between the two publicity factors (public and private)

Hypothesis 4: At least one of the study manipulation factors (social interaction and publicity) influences EEG power.

Previous social exclusion studies demonstrated that a decrease in frontal theta could be a marker for social exclusion (Cristofori et al., 2012; van Noordt et al., 2015; Wang et al., 2017).Thus, socially negative interactions were predicted to present an increase in theta EEG power at the frontal region in comparison with socially positive interactions. Moreover, Yoon and Chung (2011) showed the existence of a relationship between theta, alpha, beta, and gamma and the experienced levels of emotion. They demonstrated that gamma is associated with anxiety while alpha was triggered high during joy and triggered low during fear and sadness. Based on this assumption, the standard frequency bands (theta, alpha, beta, and gamma) were investigated independently. Thus, socially negative interactions were predicted to present EEG power significantly different from socially positive interactions at each of the standard frequency bands. In this investigation, the brain cortex was divided into five spatial regions (left anterior, right anterior, left posterior, right posterior and midline). Moreover, it was predicted that cyberbullying in public induces a significant difference in comparison with the private form as reflected in EEG power for each of the standard frequency bands by each of the selected brain's five spatial regions.

H_{4a} = There is a significant difference in EEG power between the two social interaction levels (social exclusion and social inclusion).

H_{4b} = There is a significant difference in EEG power between the two publicity levels (public and private).

Hypothesis 5: EEG signatures due to cyberbullying are associated with positive affect and negative affect.

H_5 = There is a correlation between EEG signatures and emotional responses due to cyberbullying.

Hypothesis 6: EEG signatures due to cyberbullying are associated with stress responses (task engagement, distress, and worry)

H_6 = There is a correlation between EEG signatures and stress responses (task engagement, distress, and worry) due to cyberbullying.

Hypothesis 7: EEG signatures due to cyberbullying is associated with coping with coping responses

H_7 = There is a correlation between EEG signatures and coping responses (task focus, emotion focus, and avoidance) due to cyberbullying.

3.2 Methods

3.2.1 Measures

3.2.1.1 Subjective Measures

Positive and Negative Affect Schedule (PANAS). The PANAS assessed subjects' affective state in two dimensions: Positive Affect "PA" and Negative Affect "NA" (Watson & Clark, 1984). PANAS has ten items dedicated to measuring positive affect (e.g., alert, attentive, active, determined and inspired) and ten items to measuring negative affect (e.g., upset, hostile, afraid, nervous, and ashamed) (Watson et al., 1988). During the experiment, the subject rated in 5 Likert-scale their feeling before starting the experiment and during each trial. The instrument possesses a good internal consistency, with Cronbach's alpha ≥ .84 for both positive affect and negative affect (Tran, 2013).

Dundee Stress State Questionnaire (DSSQ-3). Stress was measured using the 30 items DSSQ-3 (Matthews et al., 2005), a highly validated short version of the original DSSQ version with an alpha scale ranging from 0.78–0.83 (Matthews et al., 2013). The recommendation to use the short version over the original lies behind the requirement to shorten the experiment time. Both versions examine the three forms of the DSSQ-3 engagement, distress, and worry. Subjects evaluate their current stress level using DSSQ-3 before starting the experimental task and after each session of the experiment.

Coping Inventory for Stressful Situations (CITS). A 21-item questionnaire designed to measure how subject copes with the stressful event was used to complimentary DSSQ-3 by Matthews and Campbell (1998). This instrument measures three coping forms (Task-focus, emotion focus, and avoidance).

3.2.1.2 Objective measures

Power Spectral Density (PSD) is a frequency domain measurement of the signal strength. It illustrates the power distribution at different frequency bands in EEG time series. EEG Emotion-related signaling has been widely investigated since the 90s using spectral analysis and ERP methods. However, power spectral analysis method was more common for emotional classification studies (Yoon & Chung, 2011).

It is known that EEG power amplitude is randomly and rapidly fluctuating over time. This randomness can be analyzed using the PSD methods by plotting power against frequency. This transformation can be conducted using a process called Fast Fourier Transform (FFT) to represent the signal as a spectrum which is the frequency content of a signal (Proakis & Manolakis, 1996). However, there are many methods used to estimate PSD. One of the most used methods is Welch method (Welch, 1967). Some studies have proven that the Welch method (a.k.a periodogram method) provides a more accurate representation of EEG features for the purpose of reducing the variance (Fadzal et al., 2014). This study estimates PSD using Welch method. EEGLAB function “spectopo” was used to calculate the PSD on each of the frequency band: theta (4-7.99Hz), alpha (8-12.99Hz), beta (13-29.99Hz) and gamma (30-50Hz) (Delorme & Makeig, 2004).

3.2.2 Stimuli and Procedure

3.2.2.1 Apparatus

EEG data acquisition was obtained using Cognionics © HD-72 (Cognionics, Inc., San Diego) mobilized dry electrode harness headset. The harness (Figure 4) is equipped with Bluetooth wireless transmission and time-marked data synchronization algorithm to obtain accurate EEG data stamping while transmitting the data to the acquisition PC. The harness had 64 electrodes configured according to 10/5 system (Oostenveld & Praamstra), each equipped with two types of dry electrodes dry pad (covers no hair areas) and flex (covers area with hair). Seven Dry-Pad electrodes covered the forehead, 54 flex electrodes were over the hairy area, and the remaining two electrodes were dedicated to the reference and ground electrodes and attached to the right mastoid and left ear (Mullen et al., 2015). The system equipped with a set of active noise reduction shield and a high input impedance amplifier. The acquisition system recorded EEG data at a sample rate of 500 Hz.

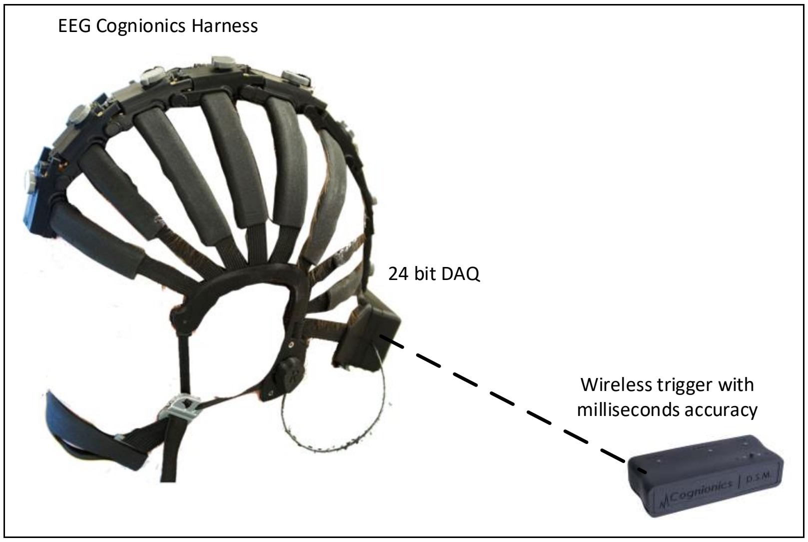

Figure 4. Wearable EEG harnesses designed by Cognionics© as modified from (http://www.cognionics.com/)

The reference and ground electrode was placed at the right mastoid and under the left ear, respectively. The device performed well in a noisy environment such as flight simulators where movement artifacts are present (Callan et al., 2015; Mullen et al., 2015).

The dry electrode is now more popular for data acquisition than wet electrode (Luck, 2014). Cognionics ERP signal quality according to (Mullen et al., 2013) proved to correlate r > 0.9 with the results acquired via the wet electrode. High impedance dry electrodes have the advantage of minimizing the EEG headset setup time (Kappenman & Luck, 2011).

Cognionics acquisition software was used to acquire EEG data via Bluetooth USB connected to the recording computer. The software used to present cyberball game was PsychoPy (Peirce, 2007). PsychoPy is an open-source Python-based experimental system licensed under GPL terms. In our setup, psychopy will be developed to present the stimulus. The game was presented to the subject on a LED screen at 1366x768 resolution with a refresh rate of 60 Hz. Psychophysics installed on PC (Windows 10 laptop equipped with 8GB Memory RAM and a hard drive of 50 GB HDD). Installed Psychopy software provided a millisecond timestamp accuracy during recording. The EEG data was stored as received from the acquisition software in a bdf format. The keyboard was wired to the computer with no mouse connected to reduce any additional possibility of motions artifacts. The apparatus setup is presented in figure 5.

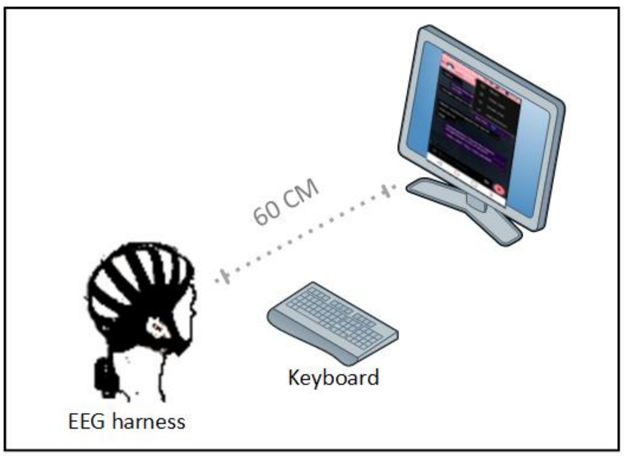

Figure 5. Apparatus setup.Subject sit 60 cm away from the screen while wearing the EEG harness

3.2.2.2 EEG Pre-processing

A band-pass filter (3Hz to 50Hz) was applied on the acquired raw EEG data using FIR filter that is part of EEGLAB toolbox (Delorme & Makeig, 2004). Next, visual inspection was conducted to reject noisy channel. After that, Artifact Subspace Reconstruction (ASR) plugin was used to remove high amplitude or high-variance artifacts Mullen et al. (2013). ASR is one of the most effective tools for removing muscle artifacts (Bulea et al., 2014; Nathan & Contreras-

Vidal, 2016). Similar to van Noordt et al. (2015), the scalp data were re-constructed using non-artefactual ICs and interpolated back to the standard 64 change montage following 10-5 system using spherical interpolation of missing channels. This plugin utilizes a sliding window protocol where each window was compared with a clean baseline data (Bulea et al., 2014). In this study, a sliding window of 500 ms and a five standard deviations threshold were used to find abnormal window. Common Average Reference (CAR) was conducted to reduce noise (Minguillon et al., 2017). Then, the continuous data were epoched between –500 and 1,500 ms (epoch's baseline was corrected from –500 to 0 ms). Rejection criteria considered locating any abnormal spectra that were between (± 50 dB) as recommended by (Delorme & Makeig, 2004). The cleaned data after that was decomposed using Independent Component Analyses (ICA) through EEGLAB "runica" function to isolate any leftover artefactual contaminated components (Delorme et al., 2007). Further, a plugin on EEGLAB called SASICA was used to reject any undetected artifacts automatically (Chaumon et al., 2015).

3.2.2.3 Experimental Stimuli

Cyberball game (Williams & Jarvis, 2006) has been widely used in behavioral and neuroimaging studies to induce social exclusion (Williams, Bernieri, et al., 2000; Williams et al., 2002; Williams & Jarvis, 2006). The validity of this intervention had been proven to induce exclusion even when the subject knows they are playing with a software (Zadro et al., 2004). Cyberball has been cited more than 200 times in social exclusion studies (Hartgerink et al., 2015). The game was originally conducted to study social interaction conditions (inclusion, exclusion) with three or more players. Thus, this game was originally designed to study social exclusion with public publicity only.

The game starts with a cover story. This cover story led the subject to believe they are playing with another player on the campus. In truth, subjects played with a pre-programmed player. This cover story is vital to the success of the experiment to “avoid demand characteristics” (i.e., where subjects unintentionally change their behavior to fit the test's purpose) (Rosenthal & Rosnow, 2009).

However, To emulate the private condition, the original cyberball three-player setting was modified by converting the third player into a wall (see figure 6). The purpose of this wall was to allow the ball to bounce back to the pre-programmed player. Thus, during the exclusion condition, the pre-programmed player passed the ball to the subject once and then keep playing the ball with the wall without passing it to the subject ball until the end of the block.

During the inclusion condition, the ball passed between players equally. During public conditions, the ball is passed between four players including the subject. During the inclusion state, the subject received the ball equally on a regular basis. However, during the exclusion condition, the subject receives the ball three times during the first ten throws, and after that, s/he was excluded until the trial ends.

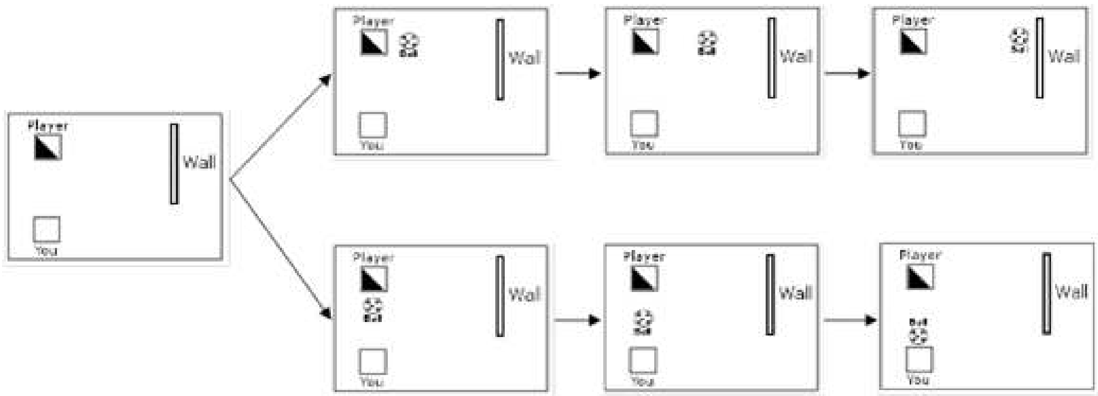

Figure 6. The modified Cyberball schematic diagram used during the private session.The ball is either passed between the subject, and the computerized participant (private-inclusion) or the computerized participant bounce the ball back on the wall (private-exclusion)

3.2.2.4 Experimental procedure

Subjects were invited to believe that they were going to participate in a study titled "Assessing online game and reading online comments." This title was intended to misguide the participants for the real purpose of the experiment. In fact, this title was intended to misguide the participants while in reality, they were taking part in two cyberbullying experiments. They were also instructed to be caffeine-free for at least 3 hours, and alcohol-free at least 24 hours, before the experiment.

Each subject read the consent and provided his/her demographics data including (body weight, height, handedness, and age). Then, the EEG harness was placed and adjusted to fit the subject head shape and size. Two ground electrodes were placed at both mastoid areas. The room was equipped with a PC running the presentation software.

After that, the experiment steps were explained, and the subject was trained on the experiment tools. The subject was seated at a distance of 60 cm from a screen in an electrically shielded room, wearing the Cognionics EEG Cap. They were instructed to sit on a chair and avoid talking to avoid any possible noise signals (i.e., Electromyography [EMG]). They were also advised to reduce with restricting their eye blink as much as possible.

There are five blocks in this experiment in which subjects played the modified cyberball game. The first block was the baseline block. In this block, subjects played the cyberball game in a neutral condition. A neutral condition in this context means a lack of exclusion, which does not necessarily mean an inclusion condition. After that, the subject was presented with the remaining four experimental blocks in random order (social exclusion in public, social inclusion in public, social exclusion on in private, social inclusion in private) randomly. Each experimental block had 50 throws. After the end of each block, the subject was requested to fill up a post-experiment questionnaire involving PANAS, DSSQ-3 and CITS scales. The sequence of the experiment executions is illustrated in figure 7.

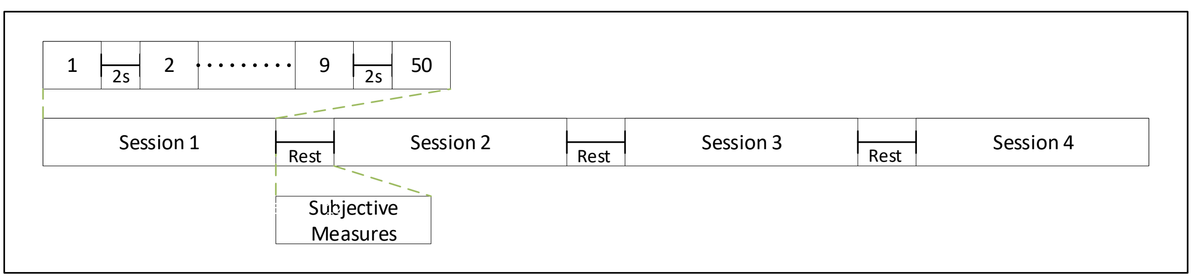

Figure 7. Social exclusion study experimental tasks.Each session includes 50 throws, and every throw takes 1.5 seconds separated between 1 to 2 second between throws. After the end of each session subject' self-assessed their feeling using PANAS, DSSQ, and CITS questionnaires

Finally, the experiment was concluded with a debriefing to reveal the purpose of the experiment and explain why it was important to have such a cover story. However, as a proactive measure the experimental debriefing recommended subjects to see UCF's counseling service if they think they were affected by the experiment.

3.2.3 Data Analysis

The analysis took a top-down approach by first analyzing the brain as one whole entity then moving down and dividing the brain regions into five regions. Finally, the EEG data were analyzed by channels. This method provides a comprehensive overview of the whole brain. The distribution of channels for each of the five-brain region is illustrated in figure 8.

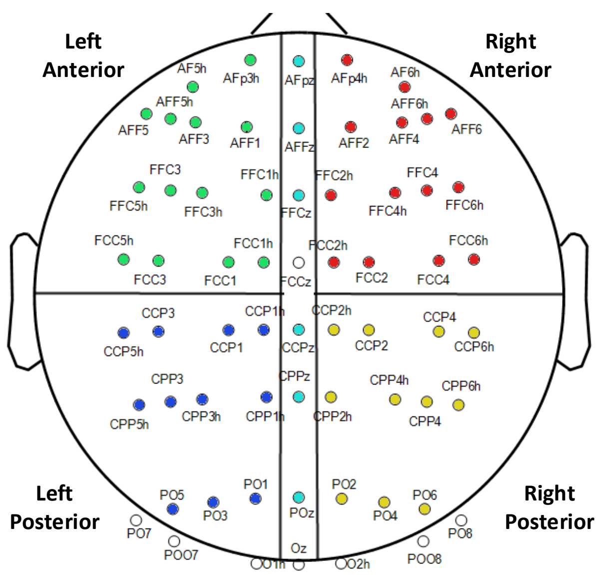

Figure 8. Social exclusion study: Brain Region of Interest (ROI)

Moreover, it is important to indicate that people exist beyond direct social interactions. Therefore, it was important to use a baseline to understand and compensate for individual difference aside from interactions. In this line of thinking, a manipulation check was computed to see first if there was a difference per condition per measure from baseline. Thus, one-way repeated measure ANOVA was used before the hypothesis testing to check if the four experimental blocks (social exclusion in public, social inclusion in public, social exclusion on in private, social inclusion in private) were significantly different from the baseline block.

Then, all set of analyses performed using repeated measures ANOVA on change scores (condition – baseline) to help control for individual differences of the starting point and to understand the magnitude of impact. Two-way repeated measure ANOVA with two levels were calculated to evaluate the effects: of cyberbullying publicity (public, private) and social interactions (social exclusion, social inclusion) on each of the dependent variables.

Repeated measures ANOVA was corrected for non-sphericity if needed using a Greenhouse–Gaiser. Pearson's correlation analysis was used to assess the degree of association between EEG signatures and the responses as reported by the PANAS, DSSQ and CITS instruments. The study significance level was set at ($p < 0.05$). Marginal significance was also reported at ($p<0.1$). Furthermore, all statistical procedures were conducted using the SPSS version 23.0 (SPSS Inc., Chicago, IL).

3.3 Results

3.3.1 Self-Report Responses

The effect of cyberbullying through social exclusion on subjective emotional and stress responses was tested in this section. Eight dependent variables of interest (Emotional responses: positive affect and negative affect; Stress responses: engagement, distress, and worry; coping responses: task-focus, emotion-focus, and avoidance) were subjectively collected before the beginning of the experiment and then after each of the sessions. Descriptive results are illustrated in Table 5. A two-way ANOVA's 2 (publicity) x 2 (social interaction) was conducted by considering the score of the magnitude of changes from the baseline.

Table 5. Social exclusion study: subjective variables (means ± SD) measured as a magnitude of changes from the baseline

	Public		Private	
	Exclusion	Inclusion	Exclusion	Inclusion
Positive Affect	-10.28 ± 7.44	-6.9 ± 8.01	-10.79 ± 6.58	-7.79 ± 6.39
Negative Affect	1.24 ± 2.61	-0.14 ± 1.94	1.66 ± 2.62	0.14 ± 2.57
Engagement	-4.79 ± 6.09	-3.21 ± 5.96	-6.21 ± 5.45	-4.34 ± 5.89
Distress	3.07 ± 4.54	1 ± 5.98	2.24 ± 5.65	0.52 ± 5.11
Worry	-1.45 ± 7.33	-2.86 ± 6.53	-2.07 ± 7.06	-1.66 ± 8.25
Task-focus	-2.59 ± 4.21	-2.1 ± 4.51	-3.59 ± 4.19	-3 ± 3.33
Emotion-focus	-4.31 ± 7.06	-5.79 ± 6.54	-4.38 ± 6.62	-5.07 ± 5.87
Avoidance	0.21 ± 4.51	-1.31 ± 3.76	0 ± 4.38	-0.72 ± 4.45

In terms of emotional responses, Social exclusion induced significantly lower positive affect than inclusion regardless of publicity [Social interaction: $F(1,28) = 11.123$, $p<.01$, $\eta_p^2 = .284$; Publicity: $F(1,28) = 1.011$, $p=.323$, $\eta_p^2 = .035$]. Inclusion induced a significantly lower negative affect than exclusion regardless of publicity [Social interaction: $F(1,28) = 16.834$, $p<.001$, $\eta_p^2 = .375$; Publicity: $F(1,28) = 1.12$, $p=.3$, $\eta_p^2 = .038$]. This indicates that negative social interaction induces negative emotional responses.

In terms of stress responses, engagement results found a marginally significant main effect for publicity [$F(1, 28) = 3.409$, $p=.075$, $\eta_p^2 = .109$] and a significant main effect for the social interaction [$F(1, 28) = 7.767$, $p<.01$, $\eta_p^2 = .217$]. The social exclusion reduced engagement in contrast to social inclusion. Distress scores showed only a significant main effect for social interaction [$F(1, 28) = 10.972$, $p<.01$, $\eta_p^2 = .282$]. Here, social exclusions evoked greater scores compared to the social inclusion. No significant main effects or interaction effect were found for worry as a dependent variable.

In terms of coping responses, avoidance scores showed only one significant main effect for social interaction [$F(1, 28) = 8.511$, $p < .01$, $\eta_p^2 = .233$]. Social exclusion conditions evoked higher score compared to social inclusion conditions. Emotion-Focus scores reported significant main effect for social interaction [$F(1, 28) = 6.343$, $p < .05$, $\eta_p^2 = .185$]. Social exclusion evoked higher Emotion-Focus score compared to social inclusion. No significant main effects or interaction effect were found for task-focus as a dependent variable. No interaction effects were found for all dependent variables. Summary of the significant results is illustrated in table 6. Figures (9-11) illustrate the trend for emotional, stress and coping with stress subjective factors.

Table 6. Social exclusion study: summary of significant subjective factors with their effect sizes

Factor	Source	Mean Square	F	Sig.	η_p^2
Positive Affect	Publicity	14.491	1.011	0.323	0.035
	Social Interaction	295.043	11.123	0.002	0.284
	Publicity * Social Interaction	1.043	0.065	0.801	0.002
Negative Affect	Publicity	3.448	1.116	0.3	0.038
	Social Interaction	60.828	16.834	0	0.375
	Publicity * Social Interaction	0.138	0.057	0.813	0.002
Engagement	Publicity	47.207	3.409	0.075	0.109
	Social Interaction	86.207	7.767	0.009	0.217
	Publicity * Social Interaction	0.552	0.041	0.841	0.001
Distress	Publicity	12.448	1.422	0.243	0.048
	Social Interaction	104.31	10.972	0.003	0.282
	Publicity * Social Interaction	0.862	0.095	0.76	0.003
Worry	Publicity	2.491	0.258	0.615	0.009
	Social Interaction	7.25	1.018	0.322	0.035
	Publicity * Social Interaction	24.216	1.582	0.219	0.053
Task_Focus	Publicity	26.078	2.543	0.122	0.083
	Social Interaction	8.284	1.16	0.291	0.04
	Publicity * Social Interaction	0.078	0.009	0.924	0
Emotion_Focus	Publicity	3.112	0.36	0.553	0.013
	Social Interaction	34.216	6.343	0.018	0.185
	Publicity * Social Interaction	4.56	0.82	0.373	0.028
Avoidance	Publicity	1.043	0.185	0.671	0.007
	Social Interaction	36.422	8.511	0.007	0.233
	Publicity * Social Interaction	4.56	0.82	0.373	0.028

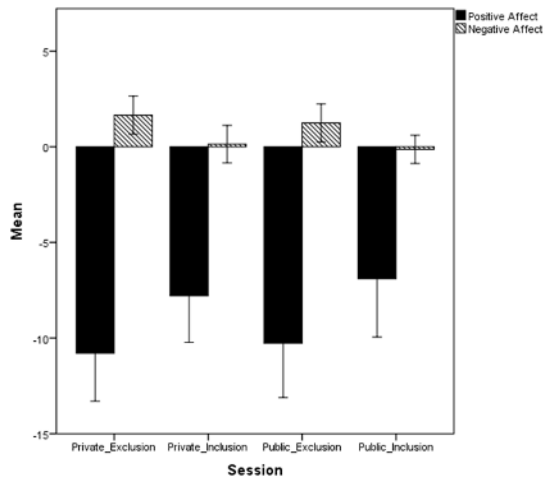

Figure 9. Social exclusion study: subjective emotional responsespresented as factors of positive affect and negative affect using PANAS. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that PA indicates Positive Affect; NA indicates Negative Affect; error bars indicate 95% confidence interval standard error. Social exclusion showed a significant increase in NA and a significant reduction in PA in contrast to social inclusion.

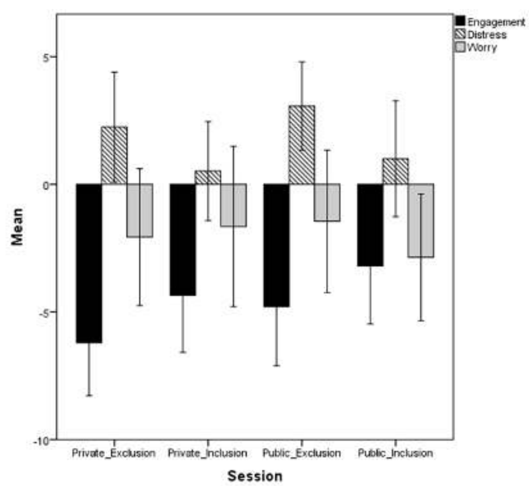

Figure 10. Social exclusion study: subjective stress responsespresented as factors of engagement, distress, and worry using DSSQ-3. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error. Social exclusion reported a significant increase in distress and a reduction in engagement in contrast to social inclusion. No main or interaction significant effect was reported for the worry dimension.

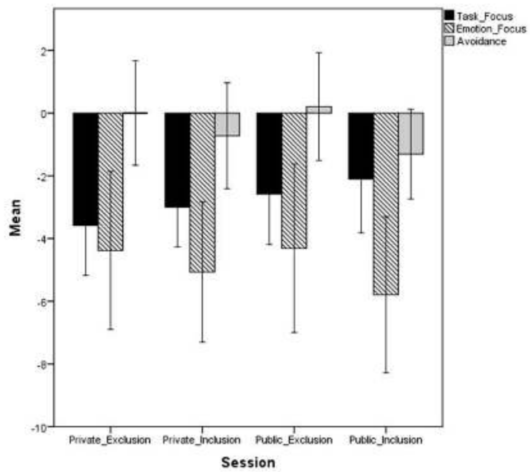

Figure 11. Social exclusion study: subjective coping responsesas factors of task-focus, emotion-focus, and avoidance using CITS. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error. Social exclusion reported a significant increase in emotions-focus and avoidance dimensions in contrast to social inclusion. No main or interaction significant effect was observed for the task focus dimension.

To further explore the results, a Pearson correlation analysis was performed (see table 7) to assess the relationship between independent variables. Distress was moderately and negatively correlated with positive affect and moderately and positively correlated with negative affect.

Table 7. Social exclusion study: Pearson correlation coefficient among subjective responses of emotional, stress and coping responses

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	Positive affect	1						
2.	Negative affect	-.348**	1					
3.	Task engagement	.596**	-.318**	1				
4.	Distress	-.432**	.580**	-.540**	1			
5.	Worry	-0.084	.266**	-.222*	.301**	1		
6.	Task-focus	.403**	-0.004	.507**	-.263**	0.164	1	
7.	Emotion-focus	-0.088	.351**	-0.094	.308**	.197*	.270**	1
8.	Avoidance	-.309**	.319**	-.501**	.280**	0.124	-0.139	.272**
	Mean	-8.94	0.72	-4.64	1.71	-2.01	-2.82	-4.89
	SD	7.232	2.535	5.876	5.375	7.243	4.066	6.48

Note: SD: Standard deviation; * p<0.05; ** p<0.01;

3.3.2 EEG power responses

3.3.2.1 Whole brain

One-way repeated measures ANOVA between the five cyberball conditions were performed to compare the grand average of the EEG power, averaged across all 64 channels and all 29 subjects. Results revealed significant differences in [theta: $F (4, 112) = 2.636$, $p < .05$, $\eta_p^2 = .086$, alpha: $F (4, 112) = 4.102$, $p < .05$, $\eta_p^2 = .128$]. Subsequent Tukey post-hoc comparison with 95% confidence interval showed that only cyberball baseline condition on alpha band was significantly different than the rest of conditions. Figure 12 illustrates the EEG power grand average for all channels all subjects.

Three-way ANOVA between [publicity (2): public and private; social interactions (2): exclusion and inclusion; and hemisphere (5): left anterior, right anterior, left posterior, right posterior and midline region] to further observe changes across the five brain regions. Results had shown that brain regions as a main effect are significantly different on theta band [$F (3, 84) =2.752$, $p=.048$, $\eta_p^2 =.089$]. Social interactions at theta band was reported as near significant [$F(3, 84)=3.459$, $p=.073$, $\eta_p^2 =.11$], toward significant at alpha band [$F(3, 84)=3.941$, $p=.057$ $\eta_p^2 =.123$)], significant at beta band [$F(3, 84)=4.766$, $p=.038$, $\eta_p^2 =.145$] and near significant main effect at gamma band [$F(3, 84)=3.47$, $p=.073$, $\eta_p^2 =.11$].

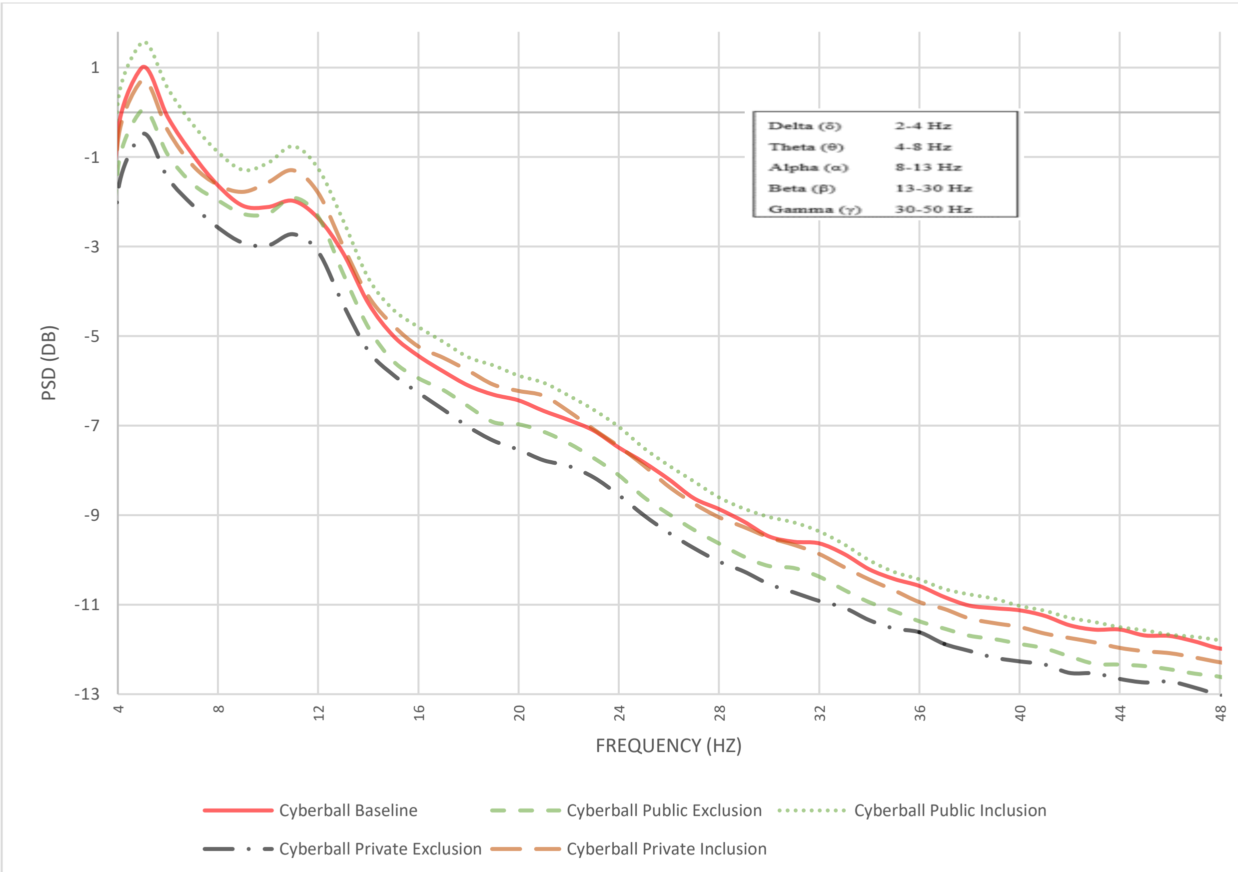

Figure 12. Social exclusion study: EEG power grand average (dB), averaged across all 64 channels and all 29 subjects. Social exclusion plotted by conditions (cyberball baseline, cyberball public exclusion, cyberball public inclusion, four frequency bands was defined as (theta: 4-8 Hz, alpha: 8-13 Hz, beta:13-30 and gamma: 30-50).

A two-way ANOVA publicity (2) x social interactions (2) on EEG power grand average (dB) across all brain found a near significant interaction effect publicity x social interactions at theta band [$F(1,28) = 3.99$, $p = .056$, $\eta_p^2 = .125$] and main effect for social at gamma band [$F(1,28) = 3.205$, $p = .084$, $\eta_p^2 = .103$].

3.3.2.2 Theta EEG power

A two-way ANOVA publicity (2) x social interactions (2) on EEG power grand average (dB) across the left anterior region found a near significant main effect of social interactions [F (1,28) =3.99, p=.063, η_p^2 = .118], near significant main effect for social interactions across left posterior region [F (1,28) =3.548, p=.07, η_p^2 = .112] with social inclusion levels evoked greater power compared to social exclusion levels, near significant main effect for publicity across right posterior region [F (1,28) =2.933, p=.098, η_p^2 = .095], near significant main effect for social interaction across right posterior brain region [F (1,28) =3.674, p=.066, η_p^2 = .116] and near significant main effect for publicity across midline brain region [F (1,28) =3.323, p=.079, η_p^2 = .106] with social inclusion levels evoking greater power compared to social exclusion levels.

Engagement showed a significant negative correlation with theta band at left posterior region, [r (116) = -.256, p < .05], at right anterior region [r (116) = -.232, p < .05] and at midline region [r (116) =-.186, p<0.05]. Avoidance showed a significant positive correlation with theta power at left posterior [r (116) =.209, p <.05]. Task-focus showed a significant correlation with theta power at right posterior [r (116) =-.189, p<.05].

3.3.2.3 Alpha EEG power

A two-way ANOVA publicity (2) x social interactions (2) on grand average of EEG power (dB) across the midline region found a near significant main effect of social interactions [F (1,28) =3.105, p=.089, η_p^2 = .1], near significant main effect for social interaction across the left anterior region [F (1,28) =3.684, p=.065, η_p^2 = .116] with social inclusion levels evoked greater power compared to social exclusion levels, near significant main effect for social interaction across the left posterior region [F (1,28) =3.708, p=.064, η_p^2 = .117] and significant main effect for social interaction across right posterior region [F (1,28) =4.378, p<.05, η_p^2 = .135] with social inclusion levels evoking greater power compared to social exclusion levels. Marginal significant effect for publicity factor across the right posterior region [F (1, 28) =4.378, p=.088, η_p^2 = .101] with private conditions evoking a greater power compared to public conditions.

Engagement showed a significant negative correlation with the alpha power at the left posterior region [r (116) = -.191, p < .05]. Task focus showed a significant negative correlation with the alpha power at the right posterior [r (116) =-.189, p<.05].

3.3.2.4 Beta EEG power

A two-way ANOVA publicity (2) x social interactions (2) on grand average of EEG power (dB) across midline region found a near significant main effect of social interactions [F (1,28) =3.47, p=.073, η_p^2 = .11], a significant main effect for social interaction across left anterior region [F (1,28) =5.6, p<.05, η_p^2 = .167] with social inclusion levels evoked greater power compared to social exclusion levels, near significant main effect for social interaction across left posterior region [F (1,28) =4.146, p=.051, η_p^2 = .129], near significant effect for social interaction across right anterior region [F(1,28) =3.942, p=.057, η_p^2 = .123] and a significant main effect for social interaction across right posterior region [F (1,28) =4.351, p<.05, η_p^2 = .135] with social inclusion levels evoking greater power compared to social exclusion levels.

Engagement showed a significant negative correlation with beta band at left posterior region, [r (116) = -.189, p < .05]. Negative affect showed a near significant negative correlation with alpha band at right anterior region [r (116)=-.180, p =.054].

3.3.2.5 Gamma EEG power

A two-way ANOVA publicity (2) x social interactions (2) on grand average of EEG power (dB) across left anterior region [$F (1,28) = 4.957$, $p < .05$, $\eta_p^2 = .15$] with social inclusion levels evoking greater power compared to social exclusion levels, near significant main effect for social interaction across left posterior region [$F (1,28) = 2.947$, $p = .097$, $\eta_p^2 = .095$] with social inclusion levels evoking greater power compared to social exclusion levels.

Engagement showed a significant negative correlation with gamma power at left posterior region [$r (116) = -.184$, $p < .05$] and at right posterior region [$r (116) = -.200$, $p < .05$].

Figures 13-17 demonstrate EEG power across brain region at each of the frequency bands studied. Table 8 provides comprehensive results of the ANOVA significant analysis for the EEG power by brain region and by frequency band. Table 9 illustrates the means and standard deviation of each spectral power. Table 10 shows Pearson correlation obtained between EEG power and the subjective variables of emotional, stress and coping responses at each of the brain regions studied.

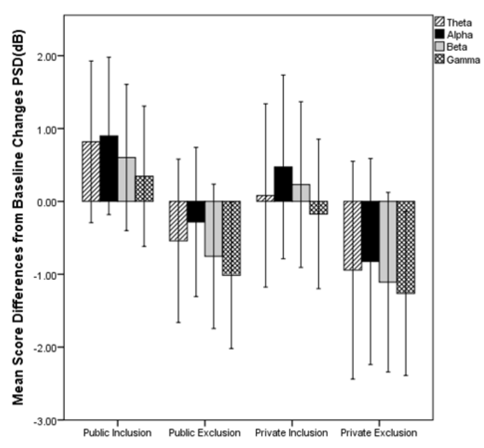

Figure 13. Social exclusion study: left anterior grand average EEG power (dB)measured as a difference from baseline changes

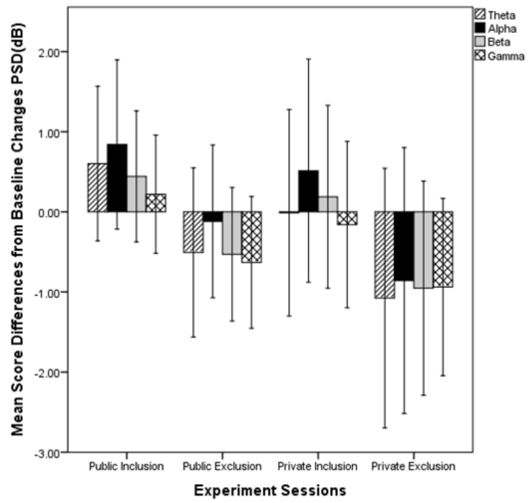

Figure 14. Social exclusion study: left posterior grand average EEG power (dB)measured as a difference from baseline changes

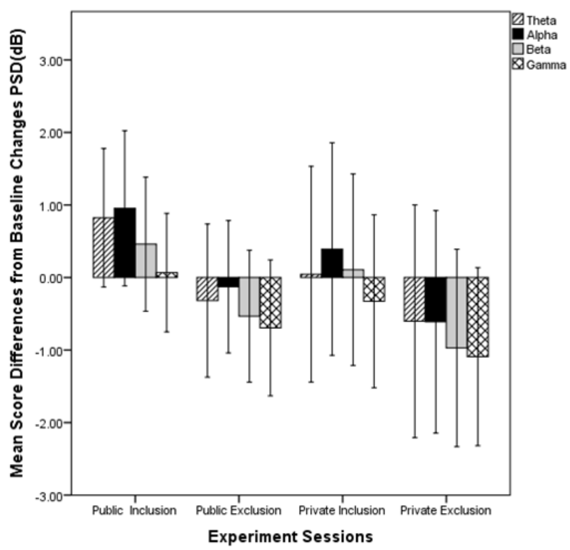

Figure 15. Social exclusion study: right anterior grand average EEG power (dB)measured as a difference from baseline changes

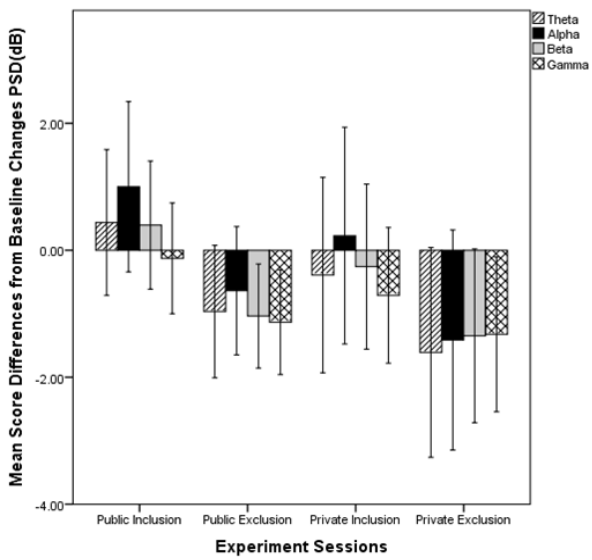

Figure 16. Social exclusion study: right posterior grand average EEG power (dB)measured as a difference from baseline changes

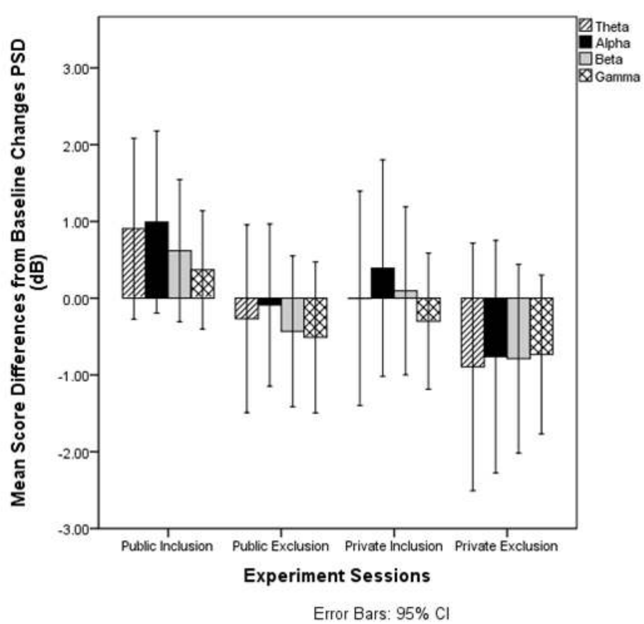

Figure 17. Social exclusion study: midline site grand average EEG power (dB)measured as a difference from baseline changes

Table 8. Social exclusion study: Summary of ANOVA for EEG power (dB) and effect sizes at each of the five brain region investigated

		Public		Private		IV	p	η_p^2
Region	Band	exclusion	inclusion	exclusion	inclusion			
Left Anterior	Theta	-0.54	0.82	-0.94	0.08	Pb	.139	.077
						SI	.063	.118
						Pb*SI	.737	.004
	Alpha	-0.28	0.9	-0.83	0.47	Pb	.18	.063
						SI	.065	.116
						Pb*SI	.906	.001
	Beta	-0.75	0.6	-1.11	0.23	Pb	.316	.036
						SI	.025	.167
						Pb*SI	.985	.000
	Gamma	-1.02	0.35	-1.26	-0.17	Pb	.313	.036
						SI	.034	.150
						Pb*SI	.729	.004
Left Posterior	Theta	-0.51	0.6	-1.08	-0.01	Pb	.208	0.056
						SI	.070	0.112
						Pb*SI	.966	0
	Alpha	-0.12	0.84	-0.86	0.51	Pb	.256	0.046
						SI	.064	0.117
						Pb*SI	.711	0.005
	Beta	-0.53	0.44	-0.95	0.19	Pb	.379	0.028
						SI	.051	0.129
						Pb*SI	.849	0.001
	Gamma	-0.63	0.22	-0.94	-0.16	Pb	0.334	0.033
						SI	0.097	0.095
						Pb*SI	0.923	0
Right Anterior	Theta	-0.32	0.82	-0.6	0.05	Pb	0.212	0.055
						SI	0.143	0.075
						Pb*SI	0.643	0.008
	Alpha	-0.13	0.95	-0.61	0.39	Pb	0.205	0.057
						SI	0.084	0.103
						Pb*SI	0.943	0
	Beta	-0.53	0.46	-0.97	0.11	Pb	0.283	0.041
						SI	0.057	0.123
						Pb*SI	0.923	0
	Gamma	-0.69	0.07	-1.09	-0.33	Pb	0.269	0.043
						SI	0.126	0.081
						Pb*SI	0.999	0
Right Posterior	Theta	-0.97	0.44	-1.61	-0.39	Pb	0.098	0.095
						SI	0.066	0.116
						Pb*SI	0.877	0.001
	Alpha	-0.64	1	-1.41	0.23	Pb	0.088	0.101
						SI	0.046	0.135
						Pb*SI	0.996	0
	Beta	-1.04	0.4	-1.35	-0.26	Pb	0.181	0.063
						SI	0.046	0.135
						Pb*SI	0.736	0.004
	Gamma	-1.13	-0.13	-1.32	-0.71	Pb	0.269	0.043
						SI	0.129	0.08
						Pb*SI	0.665	0.007

Note: IV: Independent Variable; PB: Publicity; SI: Social Interaction

		Public		Private		IV	p	η_p^2
Region	Band	exclusion	inclusion	exclusion	inclusion			
Midline site	Theta	-0.27	0.91	-0.9	0	Pb SI Pb*SI	0.079 0.114 0.812	0.106 0.087 0.002
	Alpha	-0.09	0.99	-0.76	0.39	Pb SI Pb*SI	0.114 0.089 0.949	0.087 0.1 0
	Beta	-0.43	0.62	-0.79	0.1	Pb SI Pb*SI	0.174 0.073 0.86	0.065 0.11 0.001
	Gamma	-0.51	0.37	-0.73	-0.3	Pb SI Pb*SI	0.14 0.155 0.607	0.076 0.071 0.01
Note: IV: Independent Variable; PB: Publicity; SI: Social Interaction								

Table 9. Social exclusion study: EEG power (dB) descriptive statistics (mean ± SD) each site of the brain region

	Left Anterior	Left Posterior	Right Anterior	Right Posterior	Midline Site
Theta	-0.15±3.32	-0.01±3.43	-0.25±3.32	-0.63±3.63	-0.07±3.6
Alpha	0.07±3.2	0.15±3.35	0.09±3.43	-0.21±3.94	0.13±3.45
Beta	-0.26±2.93	-0.23±3.03	-0.21±2.79	-0.56±3.05	-0.13±2.81
Gamma	-0.53±2.75	-0.51±2.78	-0.38±2.47	-0.82±2.66	-0.29±2.43

Table 10. Social exclusion study: Pearson correlations results at each of the five brain regions

Dependent variables	Brain region	Theta	Alpha	Beta	Gamma
Negative affect	LA	-	-	-	-
	RA	-	-.182*	-	-
Task engagement	LP	-.256**	-.191*	-.189*	-.184*
	RA	-.232*	-	-	-
	RP	-	-	-	-.200*
	Midline	-.186*	-	-	-
Avoidance	LP	0.209**	-	-	-
	RA	-	-	-	-
Emotion focus	LP	-	-	-	-
Task focus	RA	-	-	-	-
	RP	-.189**	-.189**	-	-

Note:
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
RA: Right Anterior; LA: Left Anterior;
LP: Left Posterior; RP: Right Posterior

3.3.2.6 EEG power Topographical Distribution

High-density topographical distribution of the pooled EEG power data in standard frequency bands to demonstrate significant channels across conditions is shown in figure 18. A two-way ANOVA publicity (2) x social interactions (2) on EEG power grand average (dB) across subjects for each channel was calculated using SPSS with a significant threshold ($p<0.05$). In theta band, there were more significant channels for the social interaction main effect in the left anterior region where inclusion evoked larger power during inclusion conditions. A comprehensive result of each of the significant channels is illustrated in table 24.

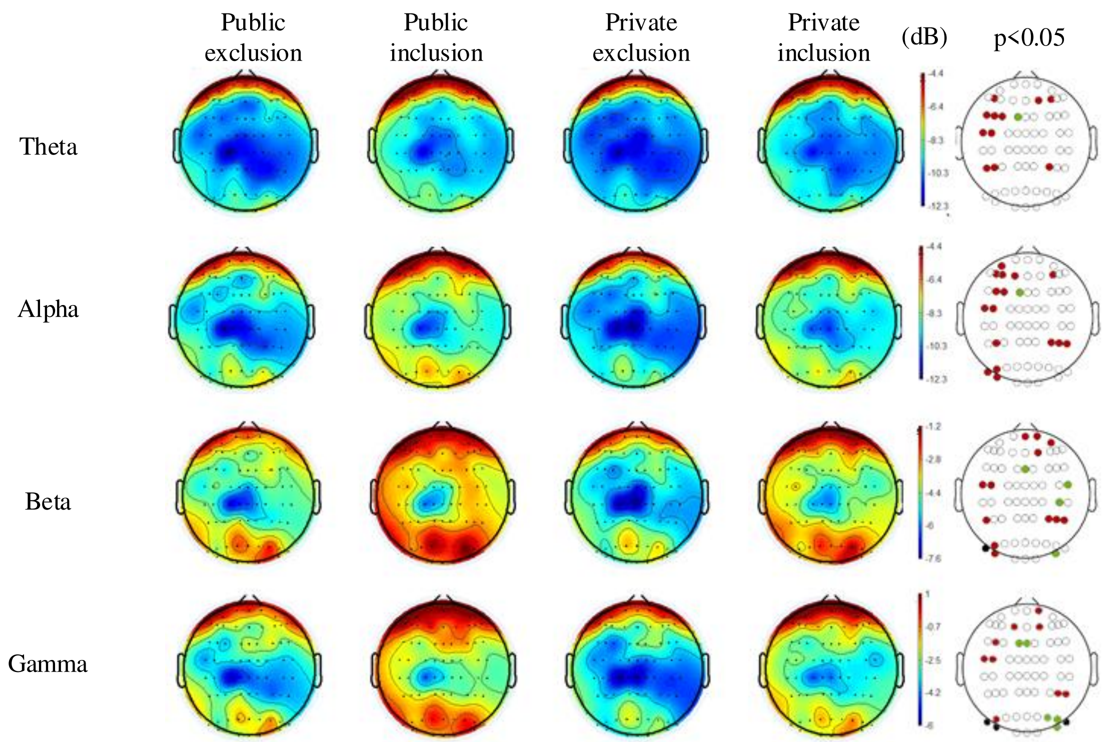

Figure 18. Social exclusion: topography of the EEG power (dB), averaged across all subjects, at each of the four frequency bands vs. (Publicity: public and private, and Social interactions: exclusion and inclusion). Empty dots indicate a not significant electrode; red dots indicate a significant electrode with social interaction as main effect, green dots indicate a significant electrode with publicity as main effect, black dots indicate a significant electrode with main effects of both publicity and social interaction. The significant threshold was set at $p<0.05$

3.3.3 Hypothesis testing

The hypotheses in this study were tested by obtaining the p-value. A hypothesis was supported if the statistical value is $p<0.05$. Table 11 summarizes the research questions and hypotheses tested.

Table 11. Social exclusion study: research question and hypothesis testing summary

Research Question	Hypothesis	Supported/Not supported	Research Answer
Do social exclusion factors (social interaction and publicity) affect emotional responses (positive affect, negative affect) among undergraduate students?	There is a significant difference in emotions between the two social interaction levels (social exclusion and social inclusion)	Supported	Social exclusion negatively affects emotions among undergraduate students in response to social interaction but not publicity.
	There is a significant difference in emotions between the two publicity levels (public and private)	Not supported	
Do social exclusion factors (social interaction and publicity) affect stress responses among undergraduate students?	There is a significant difference in stress (task engagement, distress, worry) between the two social interaction levels (social exclusion and social inclusion)	Partially supported	Social exclusion affects stress (task engagement, distress) among undergraduate students in response to social interaction but not publicity. Worry appears not to be affected by social exclusion.
	There is a significant difference in tress (task engagement, distress, worry) between the two publicity levels (public and private)	Not supported	
Do social exclusion factors (social interaction and publicity) affect in coping responses among undergraduate students?	There is a significant difference in coping (task focus, emotion focus, and avoidance) between the two social interaction levels (social exclusion and social inclusion)	Partially supported	Social exclusion affects coping (emotion focus and avoidance) among undergraduate students in response to social interaction but not publicity.
	There is a significant difference in emotions between the two publicity factors (public and private)	Not supported	
What are the brain regions and their associated frequency bands that have shown in EEG power between the two social interaction levels (social exclusion, social inclusion) in terms of (social interaction and publicity) among undergraduate students?	There is a significant difference in EEG power between the two social interaction levels (social exclusion, social inclusion)	Partially supported	Beta and gamma EEG powers in the left anterior brain region were significantly different due to social interaction levels but not publicity. Alpha and beta in the right posterior regions were significantly different due to social interaction levels but not publicity.
	There is a significant difference in EEG power between the two publicity factors (public and private)	Not supported	
What are the brain regions and their associated frequency bands that have shown significant association with emotional responses (positive affect, negative affect)?	There is a significant correlation between EEG signatures and emotional responses due to social exclusion.	Partially supported	Only right anterior alpha power was negatively correlated with negative affect
What are the brain regions and their associated frequency bands that have shown significant association with stress responses (task engagement, distress, worry)?	There is a significant correlation between EEG signatures and stress responses (task engagement, distress, and worry) due to social exclusion.	Partially supported	Engagement was negatively correlated with theta in left posterior, right anterior and midline brain regions. Engagement was negatively correlated with all frequency bands in the left posterior brain region.
What are the brain regions and their associated frequency bands that have shown significant association with coping responses (task focus, emotion focus, avoidance)?	There is a significant correlation between EEG signatures and coping responses (task focus, emotion focus, avoidance) due to social exclusion.	Partially supported	Avoidance was positively correlated with left posterior theta power. Task focus was negatively correlated with theta and alpha powers in the right posterior brain region

3.4 Discussion and Conclusion

3.4.1 Self-reported responses

It was predicted that social exclusion would induce negative emotional reactions. This emotional reaction was a function of two independent dimensions (positive affect and negative affect). This hypothesis is supported. It indicates that if a person being socially excluded, he might feel a lower level of positive affect and an increased level of negative affect. However, publicity as a factor did not show any significant effect on emotional responses. This result is consistent with the similar finding by Menesini et al. (2012).

It was also predicted that a person being socially excluded would have a lower level task engagement, higher level of distress and a higher level of worry than a person who is included in the game. Research outcome demonstrated that there was stress due to social exclusion as explained by a lower level of task engagement and increase of distress only compared to social inclusion. Being cyberbullied increases the level of distress (Sticca & Perren, 2013). The resulting analysis did not show any significant effect of worry. However, according to a study by Ortega et al. (2012), almost 25% of the participants are not worried if they were being cyberbullied.

This third hypothesis tended to evaluate how a cyberbullied individual would cope with being cyberbullied. It was expected that being cyberbullied will decrease task-focus level, increase the level of emotion-focus and increase the level of avoidance. This hypothesis was supported. However, the literature had a mix output to the coping strategy. It was reported that most of the cyberbullied individuals cope with cyberbullying incidents by ignoring the situation

(Šléglová & Cerna, 2011; Völlink, Bolman Catherine, et al., 2013; Völlink, Bolman, et al., 2013).

3.4.2 EEG power responses

This study examined each of the EEG standard frequency band (theta, alpha, beta, and gamma) on each of the brain regions independently. During social exclusion level, It was expected to see a significant difference in theta activities during negative social interactions with an increase in the frontal region based on the previous research findings (Cristofori et al., 2012; van Noordt et al., 2015). This expectation was influenced by another study finding where negative feedback had shown an increase in the EEG theta power (Cohen et al., 2007). Contrary to the expectation, this study reported marginal significant affect theta power in the left anterior and posterior brain regions. It also found left anterior theta power was greater for “inclusion” conditions compared to “exclusion” conditions regardless of the publicity factors. Moreover and to support this finding, self-reported distress was negatively correlated to slow wave ERP at the left/medial anterior in an experiment with a sample of undergraduate students (Crowley et al., 2010). In this respect, increased of theta power at the frontal midline had been noticed during emotionally positive events (Aftanas & Golocheikine, 2001) and blissful music (Sammler et al., 2007). Frontal theta power was also found to be negatively correlated with anxiety and mental stress measures (Mizuki et al., 1992). Affective distress is related to frontal lobe executive functions (Luu et al., 2000). The finding in this study indicates that theta in left frontal brain region might be a determinant of the subject reactions to exclusions.

No emotional responses were reported to be significantly correlated with theta power. However, it was observed that theta in left posterior and right anterior was negatively associated with the modulation of the task engagement. Thus, an increase of the theta power can yield to a reduction of task engagement. However, an increase of task engagement was associated with an increase in positive affect and decrease of negative affect.

At the alpha frequency band, it was expected to see a lower spectral amplitude during social exclusions based on the literature of (Davidson, 1993). Davidson (1993) supported that alpha power in the right posterior region is associated with subjective emotional responses while alpha power at both left- and right- anterior regions may be related to the perceived emotions. This study found that alpha power to be significantly different at the right posterior region and a marginally significant in the remaining of the brain regions. However, it failed to find a significant correlation between alpha and the subjective emotional responses. This is consistent with van Noordt et al. (2015) who observed alpha to be significant during social exclusion. Conversely, higher alpha power was found to be related to anxiety (Knyazev et al., 2008). Alpha power had been associated with positive events in affective studies (Aftanas et al., 2001). Decreased alpha power over the brain left regions were reported to be associated with cognitive reappraisal (Parvaz et al., 2012).

EEG social exclusion results demonstrated a significant decrease in the gamma power in the left anterior brain regions compared to social inclusion. The decrease in gamma power in response to negative words was observed on the individual with schizophrenia (Siegle et al., 2010). Gamma band activities were observed in studies of emotional memory (Headley & Pare, 2013), semantic association and working memory (Siegle et al., 2010). Left frontal gamma power decreased when individuals try to maintain their emotions (Kang et al., 2014).

A channel by channel visual inspection on the EEG topographical map demonstrated significant EEG Theta power in the left anterior channels (AFF5h, FFC5h FFC3, FFC3h, FCC5h, and FCC3) and right anterior channels (AFF2 and AFF4). This signifies that frontal theta might be a biomarker for social exclusion.

This study also observed a correlation between EEG power and task engagement as stress response during social exclusion levels in both publicity type. Accordingly, engagement is linked to the cognitive processes due to emotions (Bauman & Newman, 2013; Lazarus, 1999; Matthews & Campbell, 1998; Matthews et al., 2010). Task engagement was reported to reflect neural arousal associated with approach behavior (Fairclough & Venables, 2006).

CHAPTER 4: STUDY TWO "EFFECTS OF CYBERBULLYING THROUGH VERBAL HARASSMENT ON EMOTIONAL, STRESS AND NEUROPHYSIOLOGICAL RESPONSES"

4.1 Introduction

Verbal harassment, in the context of this study, is text-based bullying that takes place during electronic social interactions. It is the most common form of bullying (Karwoski & Summers, 2016). Individual bullied via both texting, and traditional bullying was more depressed than those who faced traditional bullying only (Raskauskas, 2009). Deficits in executive functioning were found to be correlated with bullying behavior for youth who engaged in antisocial and aggressive behaviors (Coolidge et al., 2004). Otten et al. (2016)inspected how the brain reacts against humiliation and what happens if this humiliation is accompanied with a laugh in public using ERP. Their experimental paradigm relies on presenting sentences in a sequence of word-by-word according to a time-stamped methodology known as Variable Serial Visual Presentation (VSVP) (Van Berkum et al., 2007).

4.1.1 Objective

The objective of this study is to investigate the effect of cyberbullying through verbal harassment on emotional, stress and neurophysiological responses. This research also examined how cyberbullying factors of social interaction and publicity affect the emotional and stress responses. This study also examined the effect of verbal harassment via impolite comments and social exclusion on emotional and stress responses.

4.1.2 Subjects

Most of the behavioral studies require large sample sizes to obtain an adequate statistical power, but in the case of EEG studies, it is different. It can take a smaller sample size to achieve such equivalent statistical power (Hensel et al., 2017; Sands, 2009). There is no exact sample size for EEG research (Budzynski, 2009). However, if you have less number of trials you have to increase the number of subjects (Woodman, 2010).

Twenty-nine undergraduate students (16 females, 13 males; mean age 18.33) volunteered for the experiment via UCF's psychology research participation system (SONA). They were recruited between July 10, 2017, and August 20, 2017. In appreciation of their efforts, they had the option of either receive class credit according to the SONA system or receive monetary compensation of $30. Demographic data were summarized in table 12. However, the subject's selection was limited to healthy individuals, right-handed, native speakers of English, and had a normal or corrected-to-normal vision with no neurological disorder. Thus, subjects in this study claimed to be healthy individuals with no known neurological or psychological diseases, free from cardiac problems and had normal to corrected vision. Subjects were advised to be caffeine-free for at least 3 hours and alcohol-free for at least 24 hours. They had the choice to either get paid the amount of between of ($5-$30) in cash or receive class credit equivalent to maximum hours of participation according to SONA system. Recruitment of almost an equal number of male and female was performed to control any possible gender confound. They were informed they were free to withdraw from the experiment anytime they wish. There were two cases of where data was excluded from the analysis, if the subject withdrew from the experiment or if their EEG measurements had an excessive number of artifacts.

Table 12. Summary of subject's demographics and anthropometric characteristics

	Female = 16			Male= 13		
Variable	Mean	S.d	Range	Mean	S.d	Range
Age (years)	18.25	0.58	18-20	18.46	1.13	18-22
Weight (kg)	131.2	25.15	90-170	164.85	42.3	110-275
Height (cm)	161.45	5.24	155- 170	177	5.54	167-188

4.1.3 Experimental Design

Two-way repeated measure experimental design was selected with cyberbullying publicity (2 levels) and social interaction (2 levels) as within-subject variables as the experimental design (see figure 19). The selection of the repeated measure was used because all subjects performed all interventions in random order.

Study 2: Verbal harassment				
Publicity	Public		Private	
Social Interaction	Impolite Comments	Complimentary Comments	Impolite Comments	Complimentary Comments

Figure 19. Verbal harassment study: design of the experiment

4.1.4 Research Variables

The independent variables in this study were cyberbullying publicity and social interaction. Each of the independent variables has two levels. That is, cyberbullying publicity: (private vs. public); social interactions (impolite "negative," vs. complimentary comments "positive"). Description of each of the independent variables is summarized in table 13. The dependent variables were EEG power, emotional responses (positive affect and negative affect), stress (task engagement, distress, and worry) and coping (task-focus, emotion-focus, and avoidance).

Table 13. Verbal harassment study independent variables description

Independent Variables	Level	Description
Cyberbullying publicity	Private	Social interaction is only limited between 2 people
	Public	Social interaction is in one group of 3 or more people
Social Interaction	Impolite comments	The subject read hypothetical impolite sentences
	Complimentary comments	The subject read hypothetical complimentary sentences

4.1.5 Hypotheses

In all, the previous theoretical and literature arguments provide some indication to link EEG with emotional and stress responses across this experiment. Therefore, and based on the previous evidence, the current study's claim the following hypotheses:

Hypothesis 1: At least one of the factors (social interaction and publicity) influences emotional responses.

Socially negative interactions "impolite comments" were predicted to present elevated negative emotional reaction in comparison to socially positive interactions "complimentary comments" as reflected by lower positive affect and a higher negative affect. Publicity was reported to be a factor of cyberbullying (Dooley et al., 2009). Cyberbullying can take a private (e.g., email) or public (e.g., Twitter or public website) (Sticca & Perren, 2013). Previous studies by Pieschl et al. (2013) and Sticca and Perren (2013) have reported that public cyberbullying form is more distressing than the private one. On another experimental study by Menesini et al.

(2012), publicity as a factor did not show relevance to cyberbullying. Thus, it is predicted that cyberbullying in public would induce a more negative emotional reaction in comparison to private form as reflected by lower positive affect and higher.

H_{1a} = There is a significant difference in emotions between the two social interaction levels (impolite comments and complimentary comments)

H_{1b} = There is a significant difference in emotions between the two publicity levels (public and private)

Hypothesis 2: At least one of the factors (social interaction and publicity) influences stress responses.

Socially negative interactions “impolite comments” were predicted to present elevated stress reaction in comparison to socially positive interactions as reflected by at least one of the following attributes: decreasing task engagement, increasing distress and/or increased worry higher. It was also predicted that cyberbullying in public would induce a more negative stressful reaction in comparison with private form as reflected by at least one of the following attributes decreasing task engagement, increasing distress and/or increase worry higher as measured by DSSQ-3.

H_{2a} = There is a significant difference in the stress level between the two social interaction levels (impolite comments and complimentary comments)

H_{2b} = There is a significant difference in the stress level between the two publicity levels (public and private)

Hypothesis 3: At least one of the study manipulation factors (social interaction and publicity) influences coping responses.

Socially negative interactions "impolite comments" were predicted to present elevated positive coping reactions in comparison to socially positive interactions "complimentary comments" as reflected by at least one of the following attributes decreasing task focus, increasing emotion-focus and/or increased avoidance. It was also predicted that cyberbullying in public would induce more negative coping responses in comparison to private form as reflected by at least one of the following attributes decreasing task focus, increasing emotion-focus and/or increased avoidance.

H_{3a} = There is a significant difference in coping responses between the two social interaction factors (impolite comments and social inclusion)

H_{3b} = There is a significant difference in coping responses between the two publicity factors (public and private)

Hypothesis 4: At least one of the study manipulation factors (social interaction and publicity) influences EEG power.

Yoon and Chung (2011) showed the existence of a relationship between theta, alpha, beta, and gamma and the experienced levels of emotion. They demonstrated that gamma is associated with anxiety while alpha was triggered high during joy and triggered low during fear and sadness. Based on this assumption, the standard frequency bands were investigated (theta, alpha, beta, and gamma) independently. Thus, socially negative interactions were predicted to present EEG power significantly different from socially positive interactions at each of the standard frequency bands. Further, this investigation was extended by dividing the brain cortex into five spatial regions (left anterior, right anterior, left posterior, right posterior and midline). Moreover, it was predicted that cyberbullying in public induces a significant difference in comparison with the private form as reflected in EEG power for each of the standard frequency bands by each of the selected brain's five spatial regions.

H_{4a} = There is a significant difference in EEG power between the two social interaction levels (impolite comments and complimentary comments).

H_{4b} = There is a significant difference in EEG power between the two publicity levels (public and private).

Hypothesis 5: EEG signatures due to cyberbullying are associated with positive affect and negative affect.

H_5 = There is a correlation between EEG signatures and emotional responses due to cyberbullying.

Hypothesis 6: EEG signatures due to cyberbullying are associated with stress responses (task engagement, distress, and worry)

H_6 = There is a correlation between EEG signatures and stress responses (task engagement, distress, and worry) due to cyberbullying.

Hypothesis 7: EEG signatures due to cyberbullying is associated with coping with coping responses

H_7 = There is a correlation between EEG signatures and coping responses (task focus, emotion focus, and avoidance) due to cyberbullying.

Hypothesis 8: Experiencing verbal harassment "impolite comments" would induce significantly different scores than social exclusion in terms of, emotional, stress and coping responses

H_{8a} = There is a significant difference in coping responses between the two social interaction factors (impolite comments and social inclusion)

H_{8b} = There is a significant difference in coping responses between the two publicity factors (public and private)

4.2 Methods

4.2.1 Measures

4.2.1.1 Subjective Measures

Positive and Negative Affect Schedule (PANAS). The PANAS assessed subjects' affective state in two dimensions: Positive Affect "PA" and Negative Affect "NA" (Watson & Clark, 1984). PANAS has ten items dedicated to measuring positive affect (e.g., alert, attentive, active, determined and inspired) and ten items to measuring negative affect (e.g., upset, hostile, afraid, nervous, and ashamed) (Watson et al., 1988). During the experiment, the subject rated in 5 Likert-scale their feeling before starting the experiment and during each trial. The instrument possesses a good internal consistency, with Cronbach's alpha ≥ .84 for both positive affect and negative affect (Tran, 2013).

Dundee Stress State Questionnaire (DSSQ-3). Stress was measured using the 30 items DSSQ-3 (Matthews et al., 2005), a highly validated short version of the original DSSQ version with an alpha scale ranging from 0.78–0.83 (Matthews et al., 2013). The recommendation to use the short version over the original lies behind the requirement to shorten the experiment time. Both versions examine the three forms of the DSSQ-3 engagement, distress, and worry. Subjects evaluate their current stress level using DSSQ-3 before starting the experimental task and after each session of the experiment.

Coping Inventory for Stressful Situations (CITS). A 21-item questionnaire designed to measure how subject copes with the stressful event was used to complimentary DSSQ-3 by Matthews and Campbell (1998). This instrument measures three coping forms (Task-focus, emotion focus, and avoidance).

4.2.1.2 Objective measures

Power Spectral Density (PSD) is a frequency domain measurement of the signal strength. It illustrates the power distribution at different frequency bands in EEG time series. EEG Emotion-related signaling has been widely investigated since the 90s using spectral analysis and ERP methods. However, power spectral analysis method was more common for emotional classification studies (Yoon & Chung, 2011).

It is known that EEG power amplitude is randomly and rapidly fluctuating over time. This randomness can be analyzed using the PSD methods by plotting power against frequency. This transformation can be conducted using a process called Fast Fourier Transform (FFT) to represent the signal as a spectrum which is the frequency content of a signal (Proakis & Manolakis, 1996). However, there are many methods used to estimate PSD. One of the most used methods is Welch method (Welch, 1967). Some studies have proven that the Welch method (a.k.a periodogram method) provides a more accurate representation of EEG features for the purpose of reducing the variance (Fadzal et al., 2014). This study estimates PSD using Welch method. EEGLAB function "spectopo" was used to calculate the PSD on each of the frequency band: theta (4-7.99Hz), alpha (8-12.99Hz), beta (13-29.99Hz) and gamma (30-50Hz) (Delorme & Makeig, 2004).

4.2.2 Stimuli and Procedure

4.2.2.1 Apparatus

EEG data acquisition was obtained using Cognionics © HD-72 (Cognionics, Inc., San Diego) mobilized dry electrode harness headset. The harness (Figure 4) is equipped with Bluetooth wireless transmission and time-marked data synchronization algorithm to obtain accurate EEG data stamping while transmitting the data to the acquisition PC. The harness had 64 electrodes configured according to 10/5 system (Oostenveld & Praamstra), each equipped with two types of dry electrodes dry pad (covers no hair areas) and flex (covers area with hair). Seven Dry-Pad electrodes covered the forehead, 54 flex electrodes were over the hairy area, and the remaining two electrodes were dedicated to the reference and ground electrodes and attached to the right mastoid and left ear (Mullen et al., 2015). The system equipped with a set of active noise reduction shield and a high input impedance amplifier. The acquisition system recorded EEG data at a sample rate of 500 Hz.

The reference and ground electrode was placed at the right mastoid and under the left ear, respectively. The device performed well in a noisy environment such as flight simulators where movement artifacts are present (Callan et al., 2015; Mullen et al., 2015).

The dry electrode is now more popular for data acquisition than wet electrode (Luck, 2014). Cognionics ERP signal quality according to (Mullen et al., 2013) proved to correlate $r > 0.9$ with the results acquired via the wet electrode. High impedance dry electrodes have the advantage of minimizing the EEG headset setup time (Kappenman & Luck, 2011).

Cognionics acquisition software was used to acquire EEG data via Bluetooth USB connected to the recording computer. The software used to present cyberball game was PsychoPy (Peirce, 2007). PsychoPy is an open-source Python-based experimental system licensed under GPL terms. In our setup, psychopy will be developed to present the stimulus. The game was presented to the subject on a LED screen at 1366x768 resolution with a refresh rate of 60 Hz. Psychophysics installed on PC (Windows 10 laptop equipped with 8GB Memory RAM and a hard drive of 50 GB HDD). Installed Psychopy software provided a millisecond timestamp accuracy during recording. The EEG data was stored as received from the acquisition software in a bdf format. The keyboard was wired to the computer with no mouse connected to reduce any additional possibility of motions artifacts. The apparatus setup is presented in figure 5.

4.2.2.2 EEG Pre-processing

A band-pass filter (3Hz to 50Hz) was applied on the acquired raw EEG data using FIR filter that is part of EEGLAB toolbox (Delorme & Makeig, 2004). Next, visual inspection was conducted to reject noisy channel. After that, Artifact Subspace Reconstruction (ASR) plugin was used to remove high amplitude or high-variance artifacts Mullen et al. (2013). ASR is one of the most effective tools for removing muscle artifacts (Bulea et al., 2014; Nathan & Contreras-Vidal, 2016). Similar to van Noordt et al. (2015), the scalp data were re-constructed using non-artefactual ICs and interpolated back to the standard 64 change montage following 10-5 system using spherical interpolation of missing channels. This plugin utilizes a sliding window protocol where each window was compared with a clean baseline data (Bulea et al., 2014). In this study, a sliding window of 500 ms and a five standard deviations threshold were used to find abnormal window. Common Average Reference (CAR) was conducted to reduce noise (Minguillon et al., 2017). Then, the continuous data were epoched between –500 and 1,500 ms (epoch's baseline was corrected from –500 to 0 ms). Rejection criteria considered locating any abnormal spectra that were between (± 50 dB) as recommended by (Delorme & Makeig, 2004). The cleaned data after that was decomposed using Independent Component Analyses (ICA) through EEGLAB "runica" function to isolate any leftover artefactual contaminated components (Delorme et al., 2007). Further, a plugin on EEGLAB called SASICA was used to reject any undetected artifacts automatically (Chaumon et al., 2015).

4.2.2.3 Experimental Stimuli

This experiment was managed via Variable Serial Visual Presentation (VSVP) procedure (Van Berkum et al., 2007). The typical paradigm used to display sentences in ERP studies is Serial Visual Presentation (SVP). SVP displays a sentence in word by word sequence at a fixed rate. This word by word presentation assures that the onset marker is linked to the critical word. SVP is still a valid presentation tool, but it does not present words in a natural reading way (Nieuwland et al., 2007). Therefore, Otten et al. (2016) and Van Berkum et al. (2007)established a procedure to overcome this problem. Their procedure is called VSVP which displays words according to variable length and based on its position within the sentence. According to their procedure word was to be measured by the following rules:

a. The non-critical word should be computed as (187ms + number of letters*27ms).
b. Maximum word length is 10.
c. Critical word and the word follow should be displayed at a fixed rate of 346ms.
d. Between each word, the screen was blank for 106ms.
e. The final word should be extended to at least 293ms.
f. Specify at least 1000ms pause until the next sentence begins.
g. All sentences should be roughly equal in length.

Between each trial, 2 seconds were added to allow the subject to blink. In this experiment, impolite statements were adapted from a list conducted by Giumetti et al. (2013); Otten et al. (2016) and Siakaluk et al. (2011). The baseline was to read neutral words adapted from (Siakaluk et al., 2011). Impolite/complimentary words were presented in a "confrontational situation" similar to (Wellsby et al., 2009). The subject was requested to use his skills to mentally visualize their experience while reading the comments. Cyberbullying publicity scenario was simulated using (Sticca & Perren, 2013) protocol which accounted Facebook as a public environment and email as a private environment. The sentences were checked pragmatically according to psychometric software Linguistic inquiry and word count "LIWC" (Chung & Pennebaker, 2007; Guillory et al., 2011). LIWC is a linguistic psychometric assessment tool that categorizes each sentence based on its pragmatic and psychological rating. The critical word is specified as the first impolite word "e.g., disgust" or a complimentary word "e.g., fabulous" (see figure 20) (Otten et al., 2016). The complimentary words are adapted from Otten et al. (2016). Each subject participated in all 4 blocks (verbal harassment in private, a complimentary in private, verbal harassment in public, a complimentary in public). Between each trial, a 2-second fixation marker appeared at the center of the screen (see figure 21).

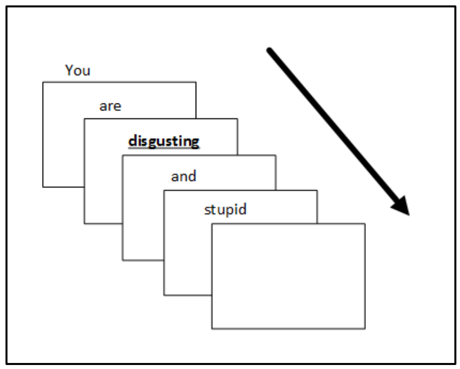

Figure 20. Verbal harassment study: illustration of the sequence sentences presentation.Bold word labels the critical word.

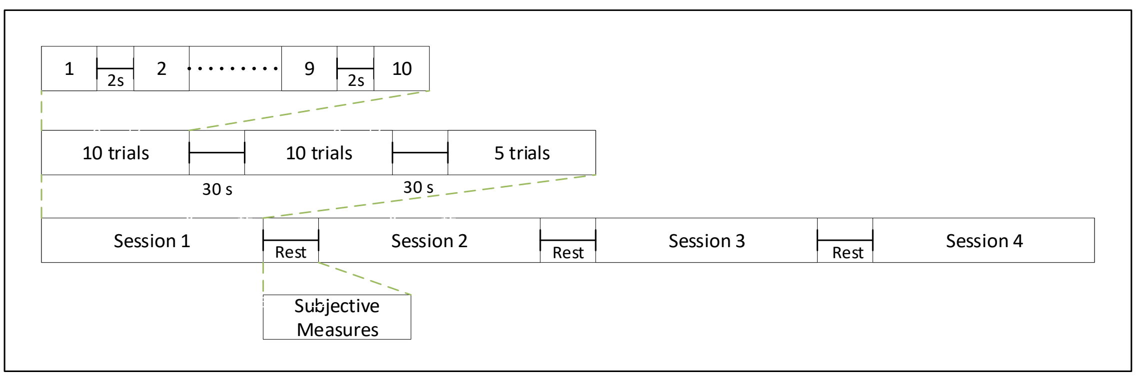

Figure 21. Verbal harassment experimental sequence.Each session includes 25 sentences. At the end of every sentence, a fixation screen was set to last between 1 to 2 seconds. After the end of every ten trails, a 30-second break was given. At the end of each session, the subject's feeling was assessed using PANAS, DSSQ and CITS questionnaires.

4.2.2.4 Experimental Procedure

Each subject read the consent and provide his/her demographics data including (body weight, height, handedness, and age). Then, the EEG harness was placed and adjusted to fit the subject head shape and size. Two ground electrodes were placed at both mastoid areas. The room was equipped with a PC running the presentation software. Before each experiment, the subject was familiarized with the upcoming task in a practice session. Then she/he randomly assigned to start with one of the two experiments. Each subject performed all interventions randomly to reduce any possible confound due to sequence effect. Each intervention is encompassing different hypothetical scenarios according to the experimental design.

After that, the experiment steps were explained, and the subject was trained on the experiment tools. The subject was seated at a distance of 60 cm from a screen in an electrically shielded room, wearing the Cognionics EEG Cap. They were instructed to sit on a chair and avoid talking to avoid any possible noise signals (i.e., Electromyography (EMG)). They were advised to reduce their eye blink as much as possible by only blinking during the fixation task. The fixation condition in this experiment was represented by a blank screen with cross at the middle of the page. Subjects were invited originally to believe that they were going to participate in a study titled “Assessing online game and reading tasks). In fact, this title was set to misguide the participant for the real purpose of the experiment, while in reality, they were taking part in a cyberbullying experiment. This experimental paradigm covers verbal harassment with a procedure utilizing Variable Serial Visual Presentation (VSVP) developed by Van Berkum et al. (2007). The subject was requested to fill up a post-experiment questionnaire PANAS, DSSQ-3 and CITS scales after each session.

Finally, the experiment was concluded with a debriefing to reveal the purpose of the experiment and explain why it was important to have such a cover story. However, as a proactive measure, the experimental debriefing recommended subjects to see UCF's counseling service if they think they were affected by the experiment

4.2.3 Data Analysis

The analysis took a top-down approach by first analyzing the brain as one whole entity then moving down and dividing the brain regions into five regions. Finally, the EEG data were analyzed by channels. This method provides a comprehensive overview of the whole brain. The distribution of channels for each of the five-brain region is illustrated in figure 22.

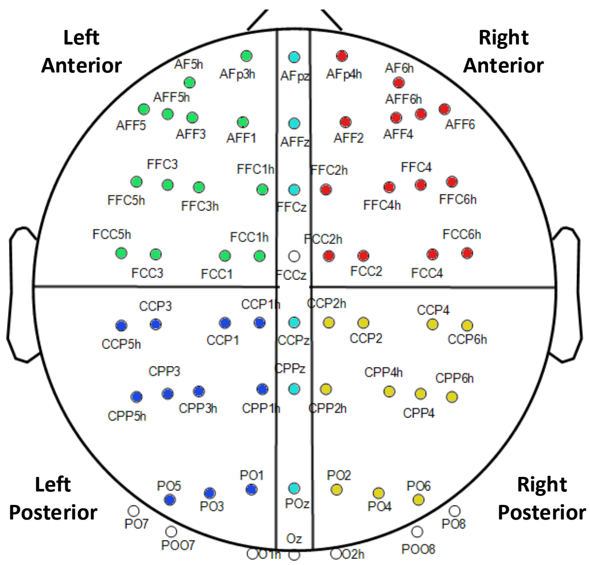

Figure 22. Verbal harassment study: Brain Region of Interest (ROI)

Moreover, it is important to indicate that people exist beyond direct social interactions. Therefore, it was important to use a baseline to understand and compensate for individual difference aside from interactions. In this line of thinking, a manipulation check was computed to see first if there was a difference per condition per measure from baseline. Thus, one-way repeated measure ANOVA was used before the hypothesis testing to check if the four experimental blocks (impolite comments in public, complimentary comments in public, complimentary comments in private, impolite comments in private) were significantly different from the baseline block.

Then, all set of analyses performed using repeated measures ANOVA on change scores (condition – baseline) to help control for individual differences of the starting point and to understand the magnitude of impact. Two-way repeated measure ANOVA with two levels were calculated to evaluate the effects: of cyberbullying publicity (public, private) and social interactions (impolite comments, complimentary comments) on each of the dependent variables.

Repeated measures ANOVA was corrected for non-sphericity if needed using a Greenhouse–Gaiser. Pearson's correlation analysis was used to assess the degree of association between EEG signatures and the responses as reported by the PANAS, DSSQ and CITS instruments. The study significance level was set at ($p < 0.05$). Marginal significance was also reported at ($p<0.1$). Furthermore, all statistical procedures were conducted using the SPSS version 23.0 (SPSS Inc., Chicago, IL).

4.3 Results

4.3.1 Self-Report Measures

The effect of cyberbullying through verbal harassment on subjective emotional and stress responses was tested in this section. Eight dependent variables of interest (Emotional responses: positive affect and negative affect; Stress responses: engagement, distress, and worry; coping responses: task-focus, emotion-focus, and avoidance) were subjectively collected before the beginning of the experiment and then after each of the sessions. Descriptive results are illustrated in Table 14. A two-way ANOVA's 2 (publicity) x 2 (social interaction) was conducted by considering the score of the magnitude of changes from the baseline.

Table 14. Verbal harassment study: subjective variables (means ± SD) measured as a magnitude of changes from the baseline

	Public		Private	
	Impoliteness	Complimentary	Impoliteness	Complimentary
Positive affect	-7.79 ± 7.6	-4.41 ± 5.59	-9.48 ± 8.18	-3.45 ± 8.37
Negative affect	2.48 ± 3.51	-0.45 ± 2.13	2.66 ± 3.3	-0.55 ± 2.05
Engagement	-2.52 ± 5.15	-1.55 ± 4.26	-3.07 ± 3.83	-1.38 ± 5.14
Distress	4.14 ± 6.57	-0.31 ± 4.4	4.41 ± 6.51	-0.48 ± 5
Worry	0.45 ± 6.38	0.24 ± 7.3	0.41 ± 6.94	-0.1 ± 6.82
Task-focus	-2.48 ± 4.19	-1.41 ± 3.35	-2.48 ± 4.4	-2.07 ± 4.37
Emotion-focus	-3.76 ± 6.59	-6.79 ± 6.19	-3.9 ± 6.53	-7.17 ± 6.27
Avoidance	-0.14 ± 3.75	-2.14 ± 3.49	0.28 ± 3.73	-2.24 ± 3.21

In terms of emotional responses, impolite comments level induced significantly lower positive affect than complimentary comments level regardless of publicity [Social interaction: $F(1,28) = 16.809$, $p < .0001$, $\eta_p^2 = .375$; Publicity: $F(1,28) = 0.299$, $p = .589$, $\eta_p^2 = .011$]. Complimentary comments induced a significantly lower negative affect than impolite comments regardless of publicity [Social interaction: $F(1,28) = 23.651$, $p < .01$, $\eta_p^2 = .458$; Publicity: $F(1,28) = 0.014$, $p = .908$, $\eta_p^2 = 0$].

In terms of stress responses, found a near significant main effect for social interaction [$F(1,28) = 4.105$, $p = .052$, $\eta_p^2 = .128$] with impolite comments reduced engagement in contrast to complimentary comments levels. Distress score showed only a significant main effect for social interaction [$F(1,28) = 19.771$, $p < .001$, $\eta_p^2 = .414$]. Impolite comments increased distress in contrast to complimentary conditions. Results for worry found a near significant main effect for social interaction [F (1,28) =4.064, p=.053, η_p^2 = .127]. Here, impolite comments evoked greater score in worry compared to complimentary comments.

In terms of coping responses, task-focus results showed a significant main effect for social interaction [F (1, 28) =15.864, p<0.01, η_p^2 = .362]. The impolite comments reduced task-focus in contrast to complimentary comments. Emotion-focus scores showed a significant main effect for social interaction [F (1, 28) =13.59, p<.01, η_p^2= .327]. Here, impolite comments evoked greater emotion-focus compared to complimentary comments. Results for avoidance reported a significant main effect for social interaction [F (1, 28) =16.809, p<0.01, η_p^2 = .375]. Impolite comments increased avoidance compared to complimentary comments. No interaction affect was found for all other dependent variables. Summary of the significant results is illustrated in table 15.

Table 15. Verbal harassment study: summary of significant subjective factors and effect sizes

Factor	Source	Mean Square	F	Sig.	η_p^2
Positive affect	Publicity	3.802	0.299	0.589	0.011
	Social Interaction	642.491	16.809	0	0.375
	Publicity * Social Interaction	51.112	2.594	0.118	0.085
Negative affect	Publicity	0.034	0.014	0.908	0
	Social Interaction	273.138	23.651	0	0.458
	Publicity * Social Interaction	0.552	0.484	0.493	0.017
Engagement	Publicity	1.043	0.296	0.591	0.01
	Social Interaction	51.112	4.105	0.052	0.128
	Publicity * Social Interaction	3.802	0.371	0.547	0.013
Distress	Publicity	0.078	0.014	0.906	0.001
	Social Interaction	633.112	19.771	0	0.414
	Publicity * Social Interaction	1.457	0.208	0.652	0.007
Worry	Publicity	3.112	0.883	0.355	0.031
	Social Interaction	15.94	4.064	0.053	0.127
	Publicity * Social Interaction	3.112	1.183	0.286	0.041
Task Focus	Publicity	1.94	0.247	0.623	0.009
	Social Interaction	288.698	15.864	0	0.362
	Publicity * Social Interaction	0.422	0.081	0.779	0.003
Emotion Focus	Publicity	0.698	0.227	0.637	0.008
	Social Interaction	147.94	13.59	0.001	0.327
	Publicity * Social Interaction	1.94	0.49	0.49	0.017
Avoidance	Publicity	3.802	0.299	0.589	0.011
	Social Interaction	642.491	16.809	0	0.375
	Publicity * Social Interaction	51.112	2.594	0.118	0.085

To further explore the results, a Pearson correlation analysis was performed (see table 16) to assess the relationship between independent variables. Distress had shown strongly negative correlation with positive affect and strongly positive correlation with negative affect.

Mean score differences from baseline changes were reported in figures 23-25.

Table 16. Verbal harassment study: Pearson correlation coefficient between subjective emotional, stress and coping responses

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
9. Positive affect	1						
10. Negative affect	-.454**	1					
11. Task engagement	.711**	-.319**	1				
12. Distress	-.714**	.689**	-.628**	1			
13. Worry	-0.14	.214*	-.305**	.339**	1		
14. Task-focus	.528**	-0.139	.511**	-.454**	-0.153	1	
15. Emotion-focus	-0.156	.225*	-0.098	0.174	-0.138	0.072	1
16. Avoidance	-.218*	.432**	-.361**	.410**	0.064	-0.013	.371**
Mean	-6.28	1.03	-2.13	1.94	0.25	-2.11	-5.41
SD	7.815	3.187	4.62	6.094	6.78	4.071	6.513

Note: SD: Standard deviation; * p<0.05; ** p<0.01;

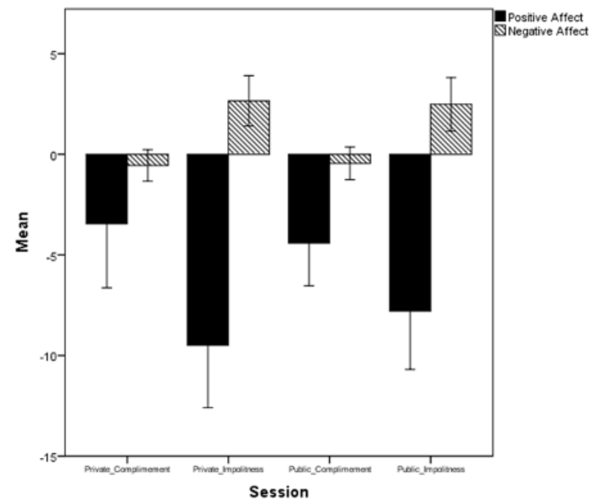

Figure 23. Verbal harassment study: subjective emotional responsespresented as factors of positive affect and negative affect using PANAS. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that PA=Positive Affect; NA=Negative Affect; error bars indicate 95% confidence interval standard error. Impolite comments levels showed a significant increase in NA and a reduction in PA in contrast to complimentary comments.

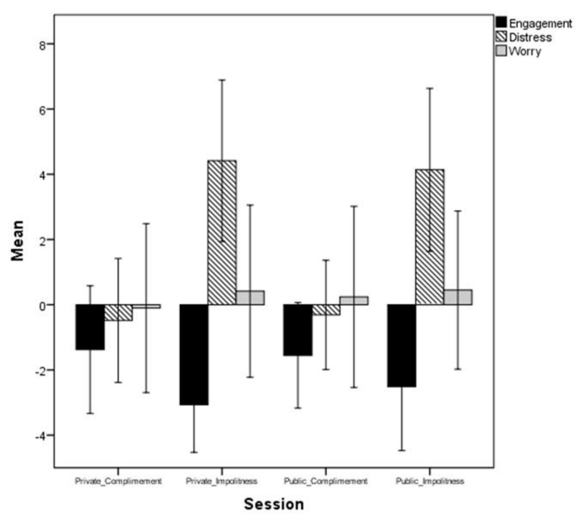

Figure 24. Verbal harassment study: subjective stress responsespresented as factors of engagement, distress, and worry using DSSQ-3. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error Impolite comments showed a significant increase in distress dimension, a near significant reduction in engagement and a near significant increase in worry dimension compared to complimentary comments.

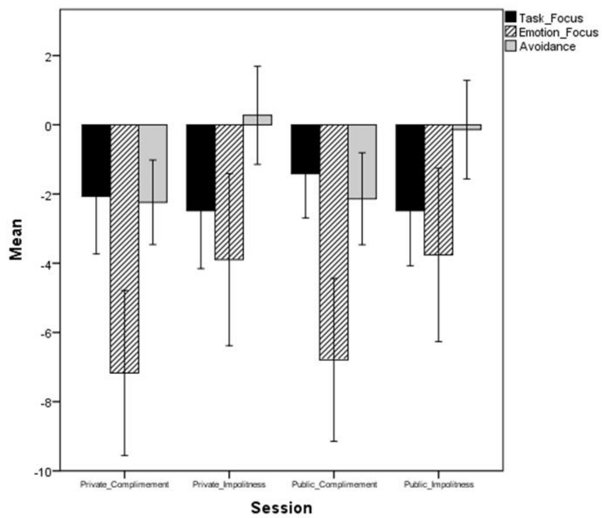

Figure 25. Verbal harassment study: subjective coping with stress responsesas factors of task-focus, emotion-focus, and avoidance using CITS. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error. Impolite comments reported a significantly reduced task focus, increased emotions-focus and increased avoidance compared to complimentary comments

4.3.2 EEG power responses

4.3.2.1 Whole brain

One-way ANOVA between the five verbal conditions was performed to compare EEG power grand average, averaged across all 64 channels and 29 subjects. Figure 26 shows the grand average for this analysis. Results revealed a near significant differences in [theta: $F(4, 112) = 2.636$, $p < .098$, $\eta_p^2 = .067$]. Post hoc pairwise comparison with 90% confidence interval showed that the significant differences were only between public-impolite comments and public-complimentary comments and between public-complimentary comments and private complimentary comments only.

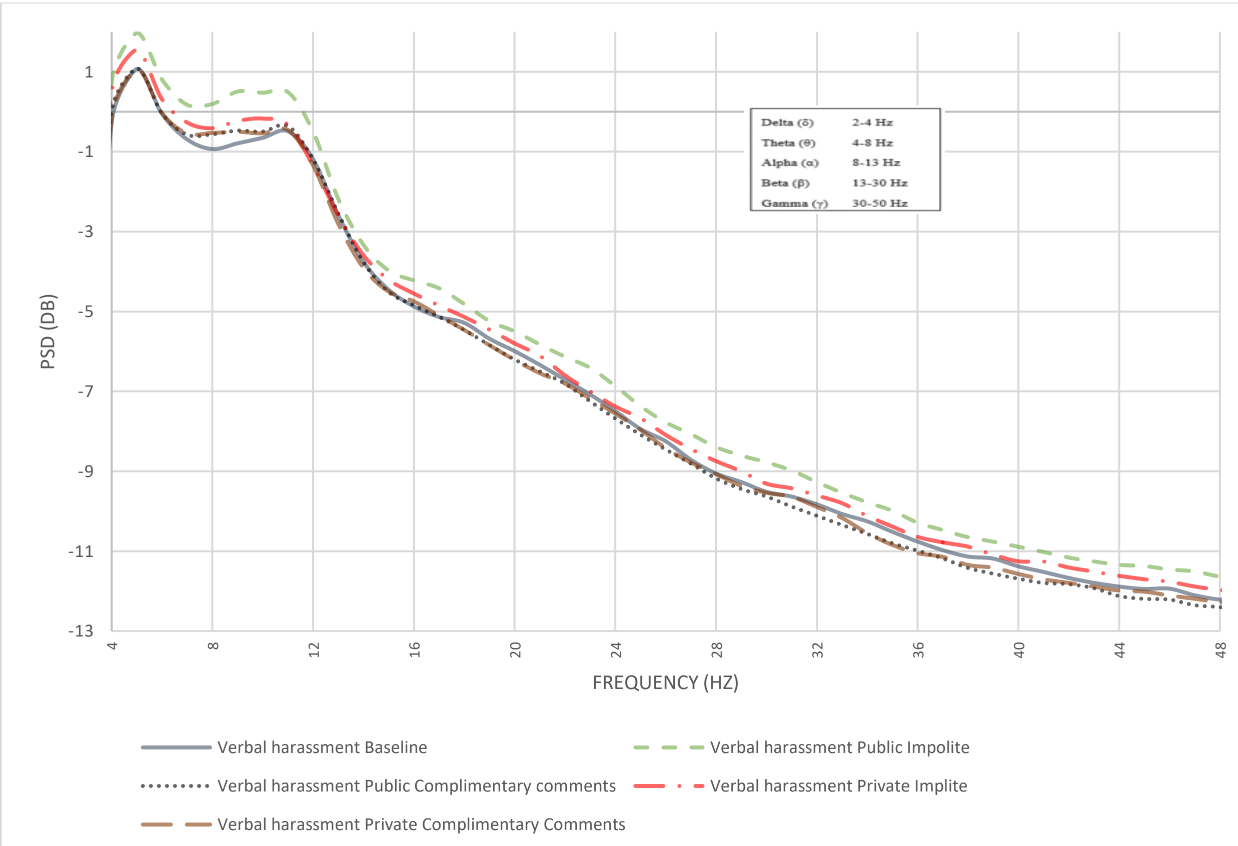

Figure 26. Verbal harassment study: EEG power grand average (dB), averaged across all 64 channels and all 29 subjects. Verbal harassment plotted by conditions (baseline, public impolite comments, public complimentary comments, private impolite comments, private complimentary comments), four frequency bands were defined as (theta: 4-8 Hz, alpha: 8-13 Hz, beta:13-30 and gamma: 30-50).

4.3.2.2 EEG by Brain regions

Three-way ANOVA between (publicity (2): public and private; social interactions (2): impolite comments and complimentary comments; and hemisphere (5): left anterior, right anterior, left posterior, right posterior and midline region) to further observe changes across the five brain regions. Results had shown no significant main effects for brain regions and publicity at theta, alpha and beta bands. Interaction effect (Brain Regions * Publicity * Social Interactions) at theta band was reported significant ($F (3, 84) = 2.86$, $p = .042$, $\eta_p^2 = .093$). Social interaction was found to be near significant at gamma band $F (3, 84) = 3.525$, $p = .071$, $\eta_p^2 = .112$).

A two-way ANOVA publicity (2) x social interactions (2) on EEG PSD grand average (dB) across all brain found a significant interaction effect publicity x social interaction at theta band [$F (1,28) = 3.99$, $p < .01$, $\eta_p^2 = .24$] and no further significant main effect was observed.

A two-way ANOVA publicity (2) x social interactions (2) on EEG PSD grand average (dB) at gamma band across the left anterior brain region found a near significant main effect of social interactions [$F (1,28) = 3.956$, $p = .057$, $\eta_p^2 = .124$], right anterior region [$F (1,28) = 3.683$, $p = .065$, $\eta_p^2 = .116$] with complimentary comments levels evoking greater power compared to impolite conditions, and near significant effect for social interaction across the midline region [$F (1,28) = 3.935$, $p = .057$, $\eta_p^2 = .123$] with complimentary comments levels evoking greater power compared to impolite levels. Figures 27-31 demonstrate EEG power per frequency band in each brain region.

Positive affect showed a significant positive correlation with gamma band at the left anterior region $r (116) = .275$, $p < .01$, at the right anterior region $r (116) = .286$, $p < .01$ and at the midline region $r (116) = .280$, $p < .01$. Engagement showed a significant positive correlation with gamma band at left anterior region $r (116) = .298$, $p < .01$, at right anterior region $r (116) = .339$, $p < .01$ and at midline region $r (116) = .299$, $p < .01$.

Distress showed a significant negative correlation with gamma band at left anterior region $r (116) = -.239$, $p < .01$, at right anterior region $r (116) = -.288$, $p < .01$ and at the midline region $r (116) = -.209$, $p < .01$. Worry showed a significant negative correlation with gamma band at the left anterior region only $r (116) = -.194$, $p < .01$. Task-focus showed a significant positive correlation with gamma band at left anterior region r (116) = .286, $p < .01$, at right anterior region r (116) = .288, $p < .01$ and at midline region r (116) =.272, $p < .01$.

Figure 27-31 demonstrate EEG power across brain region at each of the frequency bands studied. Table 17 provides comprehensive results of the ANOVA significant analysis for the EEG power by brain region and by frequency band. Table 18 illustrates the means and standard deviation of each spectral power. Table 19 shows Pearson correlation obtained between EEG power and the subjective variables of emotional, stress and coping responses at each of the brain regions studied.

Table 17. Verbal harassment study: Summary of ANOVA for EEG power (dB) and effect sizes at each of the five-brain region investigated

		Public		Private		IV	p	η_p^2
Region	Band	Impolite	Compl.	Impolite	Compl.			
Left Anterior	Theta	1.05	0.27	0.64	0.13	Pb SI Pb*SI	0.552 0.201 0.766	0.013 0.058 0.003
	Alpha	0.83	0.17	0.35	-0.06	Pb SI Pb*SI	0.434 0.261 0.77	0.022 0.045 0.003
	Beta	-0.75	0.02	0.59	0.08	Pb SI Pb*SI	0.152 0.777 0.138	0.072 0.003 0.077
	Gamma	0.94	-0.08	0.67	0.03	Pb SI Pb*SI	0.852 0.057 0.593	0.001 0.124 0.01
Left Posterior	Theta	1.21	0.22	0.28	0.42	Pb SI Pb*SI	0.374 0.382 0.191	0.028 0.027 0.06
	Alpha	0.69	0.03	-0.17	0.05	Pb SI Pb*SI	0.297 0.676 0.33	0.039 0.006 0.034
	Beta	-0.79	-0.15	-0.04	0.08	Pb SI Pb*SI	0.223 0.338 0.479	0.052 0.033 0.018
	Gamma	0.4	-0.34	-0.02	-0.04	Pb SI Pb*SI	0.828 0.19 0.201	0.002 0.061 0.058
Right Anterior	Theta	0.94	0.2	0.56	0.07	Pb SI Pb*SI	0.617 0.237 0.768	0.009 0.05 0.003
	Alpha	0.76	-0.03	0.18	-0.17	Pb SI Pb*SI	0.446 0.284 0.601	0.021 0.041 0.01
	Beta	-0.69	-0.19	0.31	-0.16	Pb SI Pb*SI	0.307 0.978 0.478	0.037 0.000 0.049
	Gamma	0.54	-0.37	0.27	-0.19	Pb SI Pb*SI	0.924 0.065 0.542	0 0.116 0.013
Right Posterior	Theta	1.24	0.26	0.42	0.27	Pb SI Pb*SI	0.382 0.233 0.333	0.027 0.05 0.033
	Alpha	1.03	0.21	0.28	-0.06	Pb SI Pb*SI	0.318 0.268 0.552	0.036 0.044 0.013
	Beta	-1.06	-0.11	0.12	-0.18	Pb SI Pb*SI	0.224 0.494 0.098	0.052 0.017 0.095
	Gamma	0.45	-0.21	0.01	-0.23	Pb SI Pb*SI	0.515 0.134 0.481	0.015 0.079 0.018

Note: IV: Independent Variable; PB: Publicity; SI: Social Interaction;
Impolite: Impolite comments; Compl.: Complimentary comments

		Public		Private		IV	p	η_p^2
Region	Band	Impolite	Compl.	Impolite	Compl.			
Midline region	Theta	0.96	0.17	0.52	0.16	Pb SI Pb*SI	0.652 0.253 0.626	0.007 0.046 0.009
	Alpha	0.61	-0.01	0.1	-0.07	Pb SI Pb*SI	0.547 0.418 0.58	0.013 0.024 0.011
	Beta	-0.82	-0.16	0.19	-0.1	Pb SI Pb*SI	0.223 0.669 0.195	0.052 0.007 0.059
	Gamma	0.54	-0.31	0.26	-0.17	Pb SI Pb*SI	0.846 0.057 0.507	0.001 0.123 0.016
Note: IV: Independent Variable; PB: Publicity; SI: Social Interaction Impolite: Impolite comments; Compl.: Complimentary comments								

Verbal harassment via impolite comments vs. social exclusion: subjective variables (means ± SD) measured as a magnitude of changes from the baseline

Table 18. Verbal harassment study: EEG power (dB) descriptive statistics (means ± SD) at each site of the brain region

	Left Anterior	Left Posterior	Right Anterior	Right Posterior	Midline Site
Theta	0.52±3.61	0.53±3.44	0.44±3.69	0.55±3.34	0.45±3.71
Alpha	0.32±3.64	0.15±3.8	0.18±3.59	0.37±3.7	0.16±3.62
Beta	-0.02±3.33	-0.22±2.98	-0.18±3.34	-0.31±3.1	-0.22±3.01
Gamma	0.39±2.93	0.00±2.2	0.06±2.95	0.01±2.31	0.08±2.52

Table 19. Verbal harassment study: Pearson correlations results at each of the five brain regions

Dependent variables	Brain region	Theta	Alpha	Beta	Gamma
Positive Affect	Midline	.262**	.289**	.302**	.280**
	Left Anterior	.234*	.271**	.301**	.275**
	Left Posterior	.270**	.265**	.316**	.304**
	Right Anterior	.246**	.233*	.304**	.286**
	Right Posterior	.215*	.232*	.269**	.199*
Engagement	Midline	.273**	.318**	.323**	.299**
	Left Anterior	.248**	.305**	.337**	.298**
	Left Posterior	.296**	.306**	.326**	.339**
	Right Anterior	.280**	.282**	.338**	.286**
	Right Posterior	.250**	.305**	.312**	.272**
Distress	Midline	-.219*	-.294**	-.271**	-.209*
	Left Anterior	-.225*	-.304**	-.302**	-.239**
	Left Posterior	-.281**	-.322**	-.346**	-.288**
	Right Anterior	-.255**	-.286**	-.302**	-.234*
	Right Posterior	-.210*	-.273**	-.271**	-.200*
Worry	Midline	-0.131	-.225*	-0.123	-0.146
	Left Anterior	-	-.213*	-	-.194*
	Left Posterior	-0.162	-.230*	-0.136	-0.173
	Right Posterior	-	-.194*	-	-
Task-Focus	Midline	.317**	.336**	.347**	.272**
	Left Anterior	.325**	.330**	.352**	.286**
	Left Posterior	.393**	.367**	.434**	.373**
	Right Anterior	.345**	.337**	.388**	.329**
	Right Posterior	.292**	.284**	.367**	.331**

Note: *. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at the 0.05 level (2-tailed).

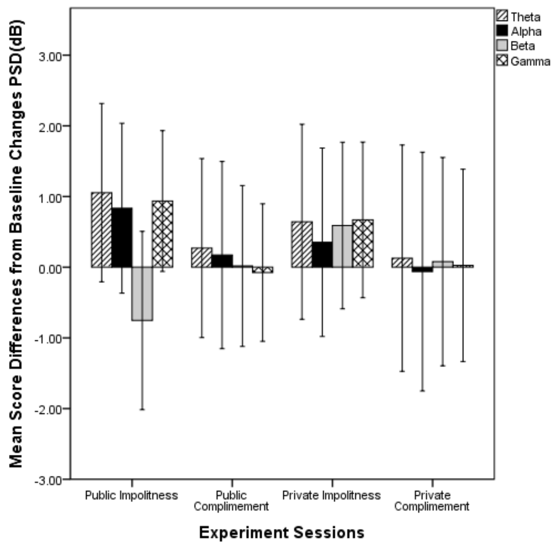

Figure 27. Verbal harassment study: left anterior grand average EEG power (dB)measured as a difference from baseline changes histogram

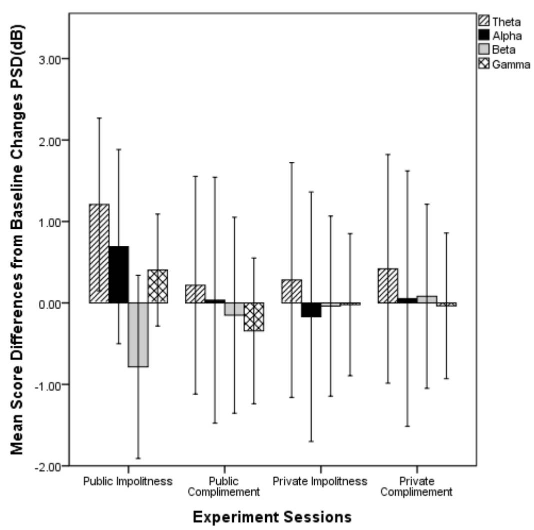

Figure 28. Verbal harassment study: left posterior grand average EEG power (dB)measured as a difference from baseline changes histogram

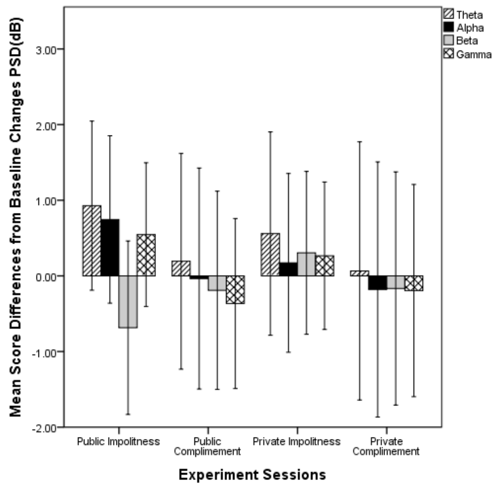

Figure 29. Verbal harassment study: right anterior grand average EEG power (dB)measured as a difference from baseline changes histogram

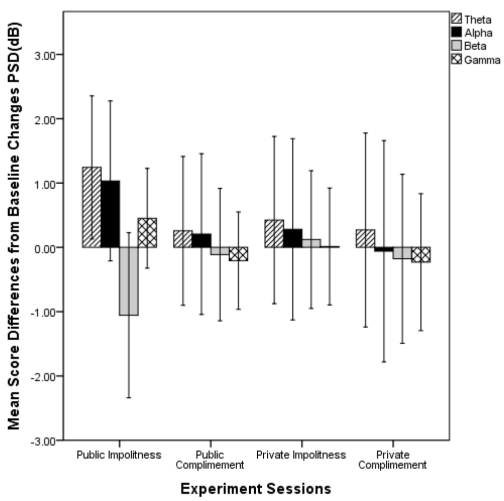

Figure 30. Verbal harassment study: right posterior grand average EEG power (dB)measured as a difference from baseline changes histogram

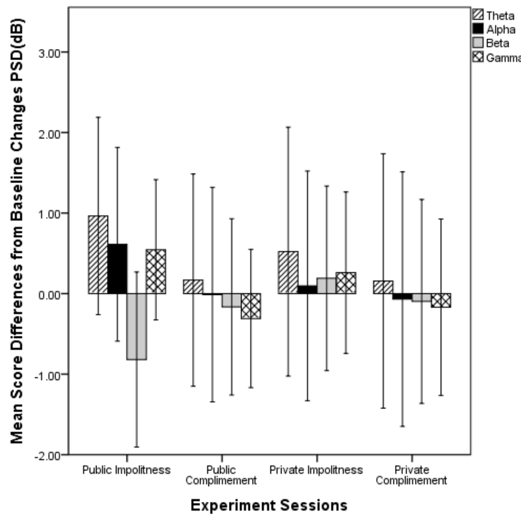

Figure 31. Verbal harassment study: midline site grand average EEG power (dB)measured as a difference from baseline changes histogram

4.3.3 EEG power Topographical Distribution

High-density topographical distribution of the pooled EEG power data in standard frequency bands to demonstrate significant channels across conditions was shown in figure 32. A two-way ANOVA publicity (2) x social interactions (2) on EEG PSD grand average (dB) across subjects for each channel was calculated using SPSS with a significant threshold ($p<0.05$). In gamma band, there were more near significant channels for the social interaction as a main effect on the left anterior region. A comprehensive result of each of the significant channels is illustrated in table 26.

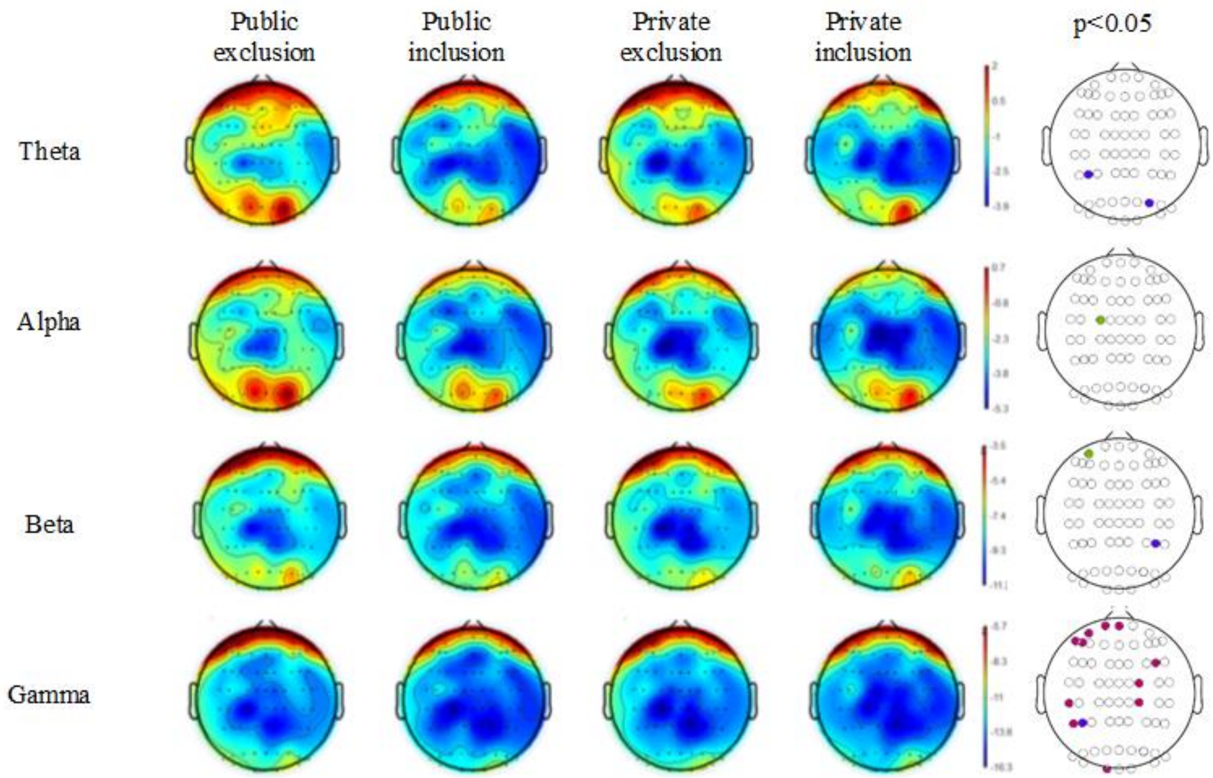

Figure 32. Verbal harassment study: topography of the EEG Power (dB), averaged across all subjects, at each of the four frequency bands vs. (Publicity: public and private, and Social interactions: impolite comments and complimentary comments). Empty dots indicate a no significant electrode, red dots indicate a significant electrode with social interaction as main effect; green dots indicate a significant electrode with publicity as main effect, black dots indicate a significant electrode with main effects of both publicity and social interaction. The significant threshold was set at $p<0.05$

4.3.4 Verbal harassment via impolite comments vs. social exclusion

The two studies in this research used the same subject in both experiments. This made it possible to compare subjective variables across the two studies. In this section, the two negative social interactions (verbal harassment via impolite comments and social exclusion) were statistically compared. Eight dependent variables of interest (Emotional responses: positive affect and negative affect; Stress responses: engagement, distress, and worry; coping responses: task-focus, emotion-focus, and avoidance) were subjectively collected before the beginning of the experiment and then after each of the sessions. Descriptive results are illustrated in Table 20. A two-way ANOVA's 2 (publicity) x 2 (social interaction) was conducted by considering the score of the magnitude of changes from the baseline.

Table 20. Verbal harassment via impolite comments vs. social exclusion: subjective variables (means ± SD) measured as a magnitude of changes from the baseline

	Public		Private	
	Impolite.	Social excl.	Impolite.	Social excl.
Positive affect	-7.79 ± 7.6	-10.28 ± 7.44	-9.48 ± 8.18	-10.79 ± 6.58
Negative affect	2.48 ± 3.51	1.24 ± 2.61	2.66 ± 3.3	1.66 ± 2.62
Engagement	-2.52 ± 5.15	-4.79 ± 6.09	-3.07 ± 3.83	-6.21 ± 5.45
Distress	4.14 ± 6.57	3.07 ± 4.54	4.41 ± 6.51	2.24 ± 5.65
Worry	0.45 ± 6.38	-1.45 ± 7.33	0.41 ± 6.94	-2.07 ± 7.06
Task-focus	-2.48 ± 4.19	-2.59 ± 4.21	-2.48 ± 4.4	-3.59 ± 4.19
Emotion-focus	-3.76 ± 6.59	-4.31 ± 7.06	-3.9 ± 6.53	-4.38 ± 6.62
Avoidance	-0.14 ± 3.75	0.21 ± 4.51	0.28 ± 3.73	0 ± 4.38

Note: Impolite. impolite comments; Social excl.: Social exclusion

In terms of emotional responses, impolite comments induced significantly incrased negative affect compared to social exclusion regardless of publicity [Social interaction: F (1,28)

=5.003, $p<.05$, $\eta p2 = .152$; Publicity: $F(1,28) = 0.568$, $p=.457$, $\eta p2 = .02$]. No significant differences in positive affect between impolite comments and social exclusion were reported.

In terms of stress responses, engagement results found a significant main effect for social interaction [$F(1,28) = 13.925$, $p<0.01$, $\eta_p^2 = .332$]. Here, social exclusion decreased in engagement score compared to impolite comments. Distress score showed a marginal significant main effect for social interaction [$F(1,28) = 3.855$, $p=.06$, $\eta_p^2 = .121$]. Here, impolite comments evoked higher score than social exclusion. Worry score showed a significant main effect for social interaction [$F(1,28) = 5.749$, $p<.05$, $\eta_p^2 = .17$]. Impolite comments induced higher in worry compared to social exclusion. In terms of coping responses, no significant difference was observed to compare impolite comments and social exclusion. Summary of the significant results is illustrated in table 21. Mean score differences from baseline changes are given in figures 33-35.

Table 21. Verbal harassment via impolite comment vs social exclusion: Summary of significant subjective factors and effect sizes

Factor	Source	Mean Square	F	Sig.	η_p^2
Positive affect	Publicity	35.31	1.636	0.211	0.055
	Social Interaction	104.31	2.216	0.148	0.073
	Publicity * Social Interaction	9.966	0.837	0.368	0.029
Negative affect	Publicity	2.491	0.568	0.457	0.02
	Social Interaction	36.422	5.003	0.033	0.152
	Publicity * Social Interaction	0.422	0.35	0.559	0.012
Engagement	Publicity	28.009	3.399	0.076	0.108
	Social Interaction	212.491	13.925	0.001	0.332
	Publicity * Social Interaction	5.388	0.641	0.43	0.022
Distress	Publicity	2.207	0.457	0.505	0.016
	Social Interaction	76.172	3.855	0.06	0.121
	Publicity * Social Interaction	8.828	0.903	0.35	0.031
Worry	Publicity	3.112	0.5	0.485	0.018
	Social Interaction	139.043	5.749	0.023	0.17
	Publicity * Social Interaction	2.491	0.397	0.534	0.014
Task Focus	Publicity	7.25	1.678	0.206	0.057
	Social Interaction	10.56	1.255	0.272	0.043
	Publicity * Social Interaction	7.25	1.23	0.277	0.042
Emotion Focus	Publicity	0.31	0.043	0.837	0.002
	Social Interaction	7.759	0.691	0.413	0.024
	Publicity * Social Interaction	0.034	0.009	0.924	0
Avoidance	Publicity	0.31	0.06	0.809	0.002
	Social Interaction	0.034	0.005	0.942	0
	Publicity * Social Interaction	2.793	1.247	0.274	0.043

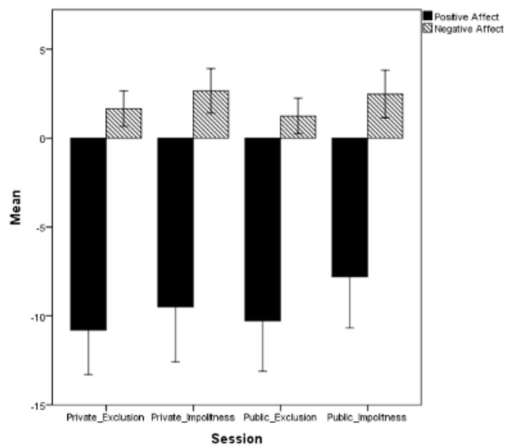

Figure 33. Subjective effects on emotional responses between the two negative social interactions (social exclusion vs. verbal harassment via impolite comments) in both experiments. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that PA=Positive Affect; NA = Negative Affect; error bars indicate 95% confidence interval standard error. Verbal harassment via impolite comments showed a significant increase in NA compared to social exclusion

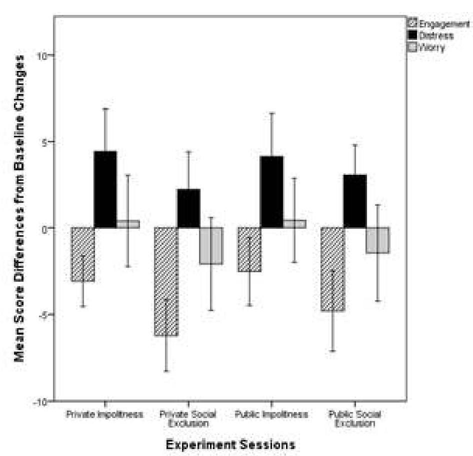

Figure 34. Subjective effects on stress responses between only the two negative social interactions (social exclusion vs. verbal harassment via impolite comments)in both experiments. subjective stress responses presented as factors of engagement, distress, and worry using DSSQ-3. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error. Impolite comments levels reported a near significant increase in distress dimension, a significant increase observed in worry dimension and a significant increase in engagement compared to social exclusion

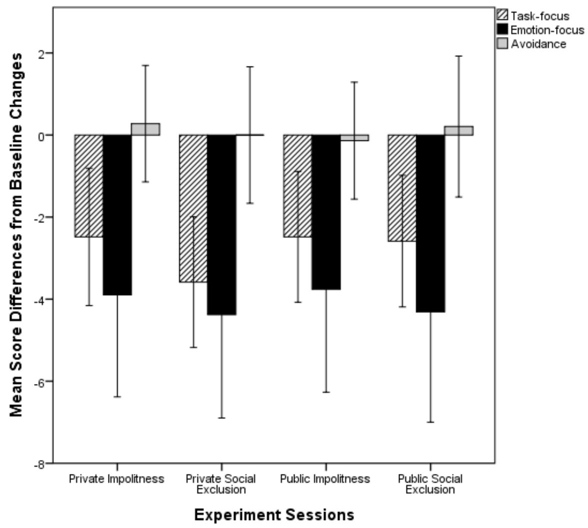

Figure 35. Subjective effects on coping responses between the two negative social interactions (social exclusion vs. verbal impolite)in both experiments. Coping responses was presented as factors of task-focus, emotion-focus, and avoidance using CITS. Scores were calculated as the magnitude of changes from baseline (condition score – baseline score). Note that error bars indicate 95% confidence interval standard error. No significant main effect difference was observed between impolite comments and social exclusion in all coping responses

4.3.5 Hypothesis testing

The hypotheses in this study were tested by obtaining the p-value. The hypothesis was supported if the statistical value is $p<0.05$. Table 22 summarize the research questions and hypotheses tested.

Table 22. Verbal harassment study: Research question and hypothesis testing summary

Research Question	Hypothesis	Supported/Not supported	Research Answer
Do verbal harassment factors (social interaction and publicity) affect emotional responses (positive affect, negative affect) among undergraduate students?	There is a significant difference in emotions between the two social interaction levels (verbal harassment and social inclusion)	Supported	Verbal harassment negatively affects emotions among undergraduate students in response to social interaction but not publicity.
	There is a significant difference in emotions between the two publicity levels (public and private)	Not supported	
Do verbal harassment factors (social interaction and publicity) affect stress responses among undergraduate students?	There is a significant difference in stress (task engagement, distress, worry) between the two social interaction levels (verbal harassment and social inclusion)	Supported	Verbal harassment affects stress (task engagement, distress, worry) among undergraduate students in response to social interaction but not publicity
	There is a significant difference in stress (task engagement, distress, worry) between the two publicity levels (public and private)	Not supported	
Do verbal harassment factors (social interaction and publicity) affect in coping responses among undergraduate students?	There is a significant difference in coping (task focus, emotion focus, and avoidance) between the two social interaction levels (verbal harassment and social inclusion)	Supported	Verbal harassment affects coping (task focus, emotion focus, and avoidance) among undergraduate students in response to social interaction but not publicity
	There is a significant difference in emotions between the two publicity factors (public and private)	Not supported	
What are the brain regions and their associated frequency bands that have shown in EEG power between the two social interaction levels (social exclusion, social inclusion) in terms of (social interaction and publicity) among undergraduate students?	There is a significant difference in EEG power between the two social interaction levels (verbal harassment, social inclusion)	Not supported	No significant effect was found in all brain regions and all frequency bands. Gamma band were found to be marginally significant in the right- and left- anterior and midline brain regions
	There is a significant difference in EEG power between the two publicity factors (public and private)	Not supported	
What are the brain regions and their associated frequency bands that have shown significant association with emotional responses (positive affect, negative affect)?	There is a significant correlation between EEG signatures and emotional responses due to verbal harassment.	partially supported	All frequency bands in all brain regions were significantly and positively correlated with positive affect only.
What are the brain regions and their associated frequency bands that have shown significant association with stress responses (task engagement, distress, worry)?	There is a significant correlation between EEG signatures and stress responses (task engagement, distress, and worry) due to verbal harassment.	partially supported	Engagement was positively correlated with all EEG frequency band in all brain regions. Distress was negatively correlated with all EEG frequency bands in all brain regions. Worry was negatively correlated with all EEG frequency bands in the left posterior and midline brain regions. Worry was negatively correlated with alpha and gamma frequency bands in the left anterior. Worry was negatively correlated with right posterior alpha power.

Research Question	Hypothesis	Supported/Not supported	Research Answer
What are the brain regions and their associated frequency bands that have shown significant association with coping responses (task focus, emotion focus, avoidance)?	There is a significant correlation between EEG signatures and coping responses (task focus, emotion focus, avoidance) due to verbal harassment.	Partially supported	Task focus was positively correlated with all EEG frequency band in all brain regions.
Is there a significant difference between cyberbullying through verbal harassment and social exclusion in terms of emotional responses?	There is a significant difference in emotions between cyberbullying through social exclusion and verbal harassment.	Partially supported	Verbal harassment induced more negative affect compared to social exclusion.
Is there a significant difference between cyberbullying through verbal harassment and social exclusion in terms of stress responses?	There is a significant difference in emotions between cyberbullying through social exclusion and verbal harassment.	Partially supported	Social exclusion reduced engagement compared to verbal harassment. Verbal harassment via impolite language increased worry compared to social exclusion.
Is there a significant difference between cyberbullying through verbal harassment and social exclusion in terms of coping responses?	There is a significant difference in emotions between cyberbullying through social exclusion and verbal harassment.	Not supported	There are no significant differences in coping between verbal harassment and social exclusion

4.4 Discussion and Conclusion

4.4.1 Self-reported responses

The first hypothesize predicted that verbal harassment would induce negative emotional reactions. This emotional reaction is a function of two independent dimensions (positive affect and negative affect). This hypothesis is supported. It indicates that if the person being verbally harassed, she/he should feel a lower level of positive affect and increase level of negative affect. However, publicity as a factor did not show any significant effect on emotional responses. This result is inconsistent with a similar finding by Menesini et al. (2012).

The second hypothesize predicted that a person being verbally harassed via impolite comments induces a lower level task engagement, higher level of distress and a higher level of worry compared to complimentary comments. Research outcome demonstrated that there was stress due to verbal harassment as explained by lower level of task engagement, increase of distress and increase of worry. Being cyberbullied increases the level of distress (Sticca & Perren, 2013).

The third hypothesis discussed the coping with stressful scenarios. This exploratory hypothesis tended to evaluate how cyberbullied individual would cope with being cyberbullied. It was expected that being cyberbullied will decrease task-focus level, increase the level of emotion-focus and increase the level of avoidance. This hypothesize was significantly supported. Most of the cyberbullied cope with being cyberbullied by ignoring the situation (Šléglová & Cerna, 2011; Völlink, Bolman Catherine, et al., 2013; Völlink, Bolman, et al., 2013).

4.4.2 EEG power responses

EEG standard frequencies were examined on each of the brain regions independently. In the literature, it had been noticed that no EEG spectral study had investigated cyberbullying explicitly. However, Otten et al. (2016)investigated verbal harassment statements using ERP. Further, studies in semantic processing and emotions were used to compare the findings in this study. It was expected that gamma power to show significant difference due to verbal harassment. EEG results demonstrated marginal significant differences between the two social interactions levels. Thus, impolite comments induced higher left- and right- anterior and midline gamma power compared to complimentary comments. Increase in gamma power in response to negative words was observed in the depressed individual (Siegle et al., 2010). The decrease in gamma power in response to negative words was observed in the individual with schizophrenia

(Siegle et al., 2010). Gamma band activities were observed in studies of emotional memory (Headley & Pare, 2013), semantic association and working memory (Siegle et al., 2010). Left frontal gamma power decreased when individual try to maintain their emotions (Kang et al., 2014).

CHAPTER 5: DISCUSSION AND CONCLUSION

5.1 Research Contribution

This research has contributed to the existing knowledge of cyberbullying. The approach for assessing cyberbullying through a combination of subjective (stress) and objective (EEG) measures should lay the basis for improving not only the theoretical basis of research in cyberbullying but the methodological approaches as well. The outcome of this study should empower current efforts of developing anti-bullying systems for combating online bullying. The results should help in the design of the bullying detection and prevention mechanisms. The ultimate understanding of the relationship between cyberbullying and EEG signatures can also facilitate the development of safer social media communication.

The current study has many implications for the research related to human psychological well-being while using the Internet. First, the study pointed that cyberbullying has a significant influence on the brain electrical signal. This outcome emphasizes that using EEG as an objective measure to assess cyberbullying incidents is possible in laboratory settings. This will help in enhancing human social safety.

5.2 Conclusion

Cyberbullying studies, in general, are still in its infancy stages (Wayne & Iain, 2014; Wright, 2017). This study demonstrated the effects of cyberbullying through social exclusion and verbal harassment on emotional, stress and neurophysiological responses. Social interaction influenced subjective emotional and stress responses in both studies. Social exclusion influenced brain activities in two brain regions (left anterior and right posterior). Left anterior beta and gamma power decreased due to social exclusion. Right posterior alpha and beta power were also engaged during social interaction. Publicity might not be a factor that influences cyberbullying through social exclusion. This study also demonstrated that EEG activities in the left anterior brain region might be an essential neural marker of social exclusion. Verbal harassment via impolite comments was more distressing compared to social exclusion.

5.3 Research Limitations

One of the main research limitations in this study is that it is designed to utilize a simulated environment to fit the laboratory settings. In real life scenarios, most cyberbullying acts are not following such ethical restrictions. It is also important to indicate that brain, as well as cyberbullying research, are still in infancy stage. It is expected with the improvement of technology, and future research design will yield to a revolution in cyberbullying detection. However, one drawback of this study is that it did not involve anger measurements explicitly. Anger was reported to exhibit the same brain area as the approach related motivation (Harmon-Jones, 2004). The results of this study revealed marginally significant effect for some EEG channels with possible trends.

This study utilizing the same subject population in different experimental approaches independently demonstrated changes in the brain EEG activities due to cyberbullying types.

The limitation of this study for future research worth mentioning. Firstly, the study relied on the mean PSD between the experimental conditions. Secondly, adding multiple biomarkers could reveal significant insights for discovering the brain reactions to cyberbullying. For example, knowing that EEG lacks the accuracy of spatial resolution, it would be beneficial if fNIRS was combined with EEG to provide spatial accuracy. Thirdly, the sample included narrow sample size with subjects aged (18-22). Future cyberbullying research should investigate the effect of age using EEG. Finally, this study approached only two types of cyberbullying. Future research should also examine the other types of cyberbullying.

5.4 Direction of Future Research

This research covered only two types of cyberbullying; future research should consider the remaining types of cyberbullying. Thus, it would be necessary to partially replicate this study by examining a methodology that can trigger the effect of social interaction. This investigation adapted methods which had shown subjective results to induce emotional reactions. Future approaches should utilize them as a valid paradigm for cyberbullying. Otten et al. (2016) used laughing on public as a paradigm to induce public humiliation. If this approach was utilized in the verbal harassment study, it might confirm the effect of publicity as a factor of cyberbullying. Future research should emphasize to conduct a computerized detection mechanism utilizing the output of this laboratory setting research. However, with the integration of new technology, neuroscience, psychology, human factors, computer science and engineering, it is expected that such detection mechanism would be possible.

APPENDIX A: INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138
To: **Ashraf M. Alhujailli** and Co-PIs: **Peter A. Hancock, Waldemar Karwowski**
Date: **December 15, 2016**

Dear Researcher:

On 12/15/2016 the IRB approved the following human participant research until 12/14/2017 inclusive:

Type of Review: UCF Initial Review Submission Form
Expedited Review
Project Title: A STUDY OF EEG SIGNATURES ASSOCIATED WITH EMOTIONAL RESPONSES AND STRESS TO CYBERBULLYING
Investigator: Ashraf M. Alhujailli
IRB Number: SBE-16-12621
Funding Agency:
Grant Title:
Research ID: N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 12/14/2017, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

IRB Chair

Page 1 of 1

APPENDIX B: MEDICAL SCREENING

Subject ID:	_______________	**Today's Date:**	____/____/_____ mm dd yy	**Height:**	___
DoB:	____/____/_____ mm dd yy			**Weight:**	___
Gender:	Female/ Male	**Race:**	American Indian Asian	Pacific Islander Others	

Which hand do you use most: (Right, Left)

____

Please circle each of the following medical screening. It will help determining your eligibility to participate in this experiment. Please be indicated that your participation is voluntary, and you may choose not to answer all questions. Please feel to refer to your copy of the consent form for more details.

Yes | No	Have you ever been diagnosed with any kind of heart diseases?
Yes | No	Have you ever been diagnosed with high blood pressure?
Yes | No	Have you had any surgery during the last six months?
Yes | No	Are you currently taking any medications?
Yes | No	Do you have any chronic disease?
Yes | No	Have seen any psychiatric or psychologist before?
Yes | No	Are you at least 24 hours since your last alcoholic drink?
Yes | No	Did you have any known mental or neurological disorders/diseases such as Epilepsy, depression, Attention Deficit Hyperactivity Disorder, etc.?

APPENDIX C: DEMOGRAPHIC QUESTIONNAIRE

Subject ID:	______________	**Today's Date:**	____/____/_____ mm dd yy	**Height:**	___
DoB:	____/____/_____ mm dd yy			**Weight:**	___
Gender:	Female / Male	**Race:**	American Indian Asian	Pacific Islander Others	

Cyberbullying Background

Please circle each of the following cyberbullying questions. Please be indicated that your participation is voluntary, and you may choose not to answer all questions. Please refer to your copy of the consent form for more details.

Have you ever experienced cyberbullying before?	Yes | No
If yes. for who long?	_______
Do you feel any of the following when you were cyberbullied?	Depressed Sad Angry Frustrated Helpless
Have you experienced any cyberbullying acts recently?	Yes | No
If yes, is it a continuous threat?	Yes | No

APPENDIX D: POSITIVE AND NEGATIVE AFFECT SCHEDULE (PANAS)

Scoring Instruction (Watson et al., 1988)

Positive Score: Add scores on items 1,3,5,9,10,12,14,16, 17, and 19

Scores can range from 10 – 50. Higher scores represent higher levels of positive affect.

Negative Score: Add scores on items 2,4,6,7,8,11,13,15,18, and 20.

Scores can range from 10 – 50, lower scores represent lower levels of negative affect.

APPENDIX E: SHORT-DUDNDE STATE STRESS QUESTIONNAIRE (DSSQ)

Scoring Instruction (Matthews et al., 2005)

Engagement = d5 + d11 + d13 + d25 - d3 - d18 - d28 - d30 + 16.

Distress = d6 + d17 + d27 + d29 - d2 - d9 - d20 - d22 + 16.

Worry = d1+d7+d10 + d12 + d16 + d19 + d21 + d26.

The range of scores. Scores will range from 0-32.

APPENDIX F: COPING INVENTORY FOR TASK STRESS (CITS)

Scoring Instruction (Matthews et al., 2005)

Summate item scores as follows:

Task-focus = 1 + 7 + 8 + 14 + 16 + 19 + 20

Emotion-focus = 2 + 5 + 6 + 11 + 12 + 13 + 15

Avoidance = 3 + 4 + 9 + 10 +17 + 18 +21

APPENDIX G: COMPREHENSIVE RESULTS TABLES

Table 23. Social exclusion: comprehensive Pearson correlations results at each of the five brain regions

	Factors	Theta	Alpha	Beta	Gamma
Midline Correlations	Positive affect	-0.082	-0.023	-0.061	-0.050
	Negative affect	-0.118	-0.144	-0.143	-0.109
	Engagement	-.186*	-0.137	-0.145	-0.156
	Distress	-0.050	-0.088	-0.088	-0.069
	Worry	0.065	0.048	0.096	0.052
	Task_Focus	-0.132	-0.137	-0.070	-0.003
	Emotion_Focus	-0.146	-0.133	-0.065	-0.012
	Avoidance	0.077	0.050	0.061	0.054
LA Correlations	Positive affect	-0.085	-0.045	-0.077	-0.075
	Negative affect	-0.117	-0.136	-0.163	-0.141
	Engagement	-0.149	-0.100	-0.081	-0.076
	Distress	-0.053	-0.087	-0.100	-0.086
	Worry	0.061	0.005	0.070	0.064
	Task_Focus	-0.114	-0.107	-0.046	0.016
	Emotion_Focus	-0.12	-0.096	-0.021	0.021
	Avoidance	0.075	0.056	0.031	0.026
LP Correlations	Positive affect	-0.13	-0.106	-0.109	-0.075
	negative affect	-0.063	-0.117	-0.085	-0.054
	Engagement	-.256**	-.191*	-.189*	-.184*
	Distress	0.057	-0.006	0.005	0.036
	Worry	0.092	0.047	0.122	0.080
	Task_Focus	-0.127	-0.135	-0.064	0.003
	Emotion_Focus	0.041	0.028	0.090	0.178
	Avoidance	.209*	0.153	0.154	0.168
RA Correlations	Positive affect	-0.116	-0.052	-0.087	-0.063
	Negative affect	-0.127	-0.182	-0.18	-0.153
	Engagement	-.232*	-0.149	-0.152	-0.137
	Distress	0.004	-0.079	-0.064	-0.033
	Worry	0.081	0.01	0.066	0.058
	Task_Focus	-0.17	-0.163	-0.093	-0.006
	Emotion_Focus	-0.084	-0.09	-0.026	0.026
	Avoidance	0.155	0.109	0.109	0.125

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
RA: Right Anterior; LA: Left Anterior;
LP: Left Posterior; RP: Right Posterior

	Factors	Theta	Alpha	Beta	Gamma
RP Correlations	Positive affect	-0.102	-0.038	-0.04	-0.037
	Negative affect	-0.114	-0.134	-0.132	-0.086
	Engagement	-0.179	-0.145	-0.164	-.200*
	Distress	-0.009	-0.037	-0.025	0.014
	Worry	0.020	0.030	0.084	0.101
	Task_Focus	-.189*	-.189*	-0.149	-0.068
	Emotion_Focus	-0.140	-0.123	-0.065	0.013
	Avoidance	0.061	0.045	0.042	0.055

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
RA: Right Anterior; LA: Left Anterior;
LP: Left Posterior; RP: Right Posterior

Table 24. Social exclusion study: channels that had shown significant in terms of EEG power (dB)

Freq	Ch. Name	Source	Mean Square	F	Sig.	η_p^2
Theta	AFF1	Social Interaction	76.19	4.386	0.045	0.135
Theta	AFF2	Social Interaction	69.463	4.41	0.045	0.136
Theta	AFp4h	Social Interaction	57.91	4.75	0.038	0.145
Theta	CPP4	Social Interaction	73.834	5.375	0.028	0.161
Theta	CPP6h	Social Interaction	72.097	5.87	0.022	0.173
Theta	FCC3	Social Interaction	84.388	7.72	0.01	0.216
Theta	FCC5h	Social Interaction	102.86	7.045	0.013	0.201
Theta	FFC1h	Publicity	28.451	6.045	0.02	0.178
Theta	FFC3	Social Interaction	51.551	4.399	0.045	0.136
Theta	FFCz	Publicity	24.14	5.862	0.022	0.173
Theta	PO4	Publicity	32.329	5.056	0.033	0.153
Theta	PO5	Social Interaction	70.438	5.791	0.023	0.171
Theta	PO6	Publicity	40.982	5.844	0.022	0.173
Theta	PO7	Publicity	53.173	6.209	0.019	0.181
Theta	PO7	Social Interaction	78.313	6.221	0.019	0.182
Theta	PO8	Publicity	41.412	5.084	0.032	0.154
Theta	PO8	Social Interaction	86.284	4.253	0.049	0.132
Theta	POO7	Publicity	36.614	4.446	0.044	0.137
Theta	POO7	Social Interaction	85.467	7.182	0.012	0.204
Theta	POO8	Publicity	60.424	8.873	0.006	0.241
Alpha	AF6h	Social Interaction	64.321	5.711	0.024	0.169
Alpha	AFF2	Social Interaction	61.555	4.518	0.042	0.139
Alpha	AFp4h	Social Interaction	59.979	6.377	0.018	0.186
Alpha	AFpz	Social Interaction	44.769	4.909	0.035	0.149
Alpha	CCP4	Publicity	32.033	4.324	0.047	0.134
Alpha	CPP4	Social Interaction	115.264	6.167	0.019	0.181
Alpha	CPP4h	Social Interaction	100.999	5.553	0.026	0.166
Alpha	CPP5h	Social Interaction	52.556	4.599	0.041	0.141
Alpha	CPP6h	Social Interaction	108.206	6.27	0.018	0.183
Alpha	FCC3	Social Interaction	91.76	6.912	0.014	0.198
Alpha	FCC5h	Social Interaction	108.518	6.717	0.015	0.193
Alpha	FCC6h	Publicity	31.58	5.104	0.032	0.154
Alpha	FFCz	Publicity	16.277	4.243	0.049	0.132
Alpha	PO5	Social Interaction	65.724	4.731	0.038	0.145
Alpha	PO7	Publicity	41.965	5.115	0.032	0.154
Alpha	PO7	Social Interaction	72.664	5.299	0.029	0.159
Alpha	POO7	Social Interaction	89.821	6.497	0.017	0.188

Freq	Ch. Name	Source	Mean Square	F	Sig.	η_p^2
Alpha	POO8	Publicity	43.503	4.674	0.039	0.143
Beta	AF5h	Social Interaction	68.598	4.424	0.045	0.136
Beta	AFF1	Social Interaction	60.645	4.88	0.036	0.148
Beta	AFF2	Social Interaction	69.332	6.014	0.021	0.177
Beta	AFF3	Social Interaction	52.694	4.528	0.042	0.139
Beta	AFF4	Social Interaction	53.799	5.156	0.031	0.156
Beta	AFF5h	Social Interaction	89.938	4.671	0.039	0.143
Beta	CPP3	Social Interaction	56.705	6.014	0.021	0.177
Beta	CPP4	Social Interaction	79.694	6.696	0.015	0.193
Beta	CPP4h	Social Interaction	66.237	6.296	0.018	0.184
Beta	CPP5h	Social Interaction	54.071	5.77	0.023	0.171
Beta	CPP6h	Social Interaction	67.313	6.163	0.019	0.18
Beta	FCC3	Social Interaction	84.984	8.052	0.008	0.223
Beta	FCC5h	Social Interaction	113.922	7.85	0.009	0.219
Beta	FFC1h	Publicity	10.057	4.362	0.046	0.135
Beta	FFC3	Social Interaction	71.095	6.751	0.015	0.194
Beta	FFC3h	Social Interaction	58.026	5.691	0.024	0.169
Beta	FFC5h	Social Interaction	71.066	5.412	0.027	0.162
Beta	PO5	Social Interaction	48.011	4.488	0.043	0.138
Beta	PO7	Social Interaction	59.5	5.569	0.025	0.166
Beta	POO7	Social Interaction	61.876	5.582	0.025	0.166
Gamma	AFF2	Social Interaction	51.517	4.361	0.046	0.135
Gamma	AFF4	Social Interaction	52.744	4.527	0.042	0.139
Gamma	AFF5h	Social Interaction	97.737	4.754	0.038	0.145
Gamma	CPP3	Social Interaction	47.831	4.983	0.034	0.151
Gamma	CPP4h	Social Interaction	34.485	4.415	0.045	0.136
Gamma	CPP5h	Social Interaction	40.793	4.707	0.039	0.144
Gamma	FCC3	Social Interaction	69.111	6.179	0.019	0.181
Gamma	FCC5h	Social Interaction	116.781	6.397	0.017	0.186
Gamma	FFC1h	Publicity	7.46	6.341	0.018	0.185
Gamma	FFC3	Social Interaction	72.396	7.451	0.011	0.21
Gamma	FFC3h	Social Interaction	43.787	5.398	0.028	0.162
Gamma	FFC5h	Social Interaction	89.191	6.319	0.018	0.184

Table 25. Verbal harassment: comprehensive Pearson correlations results at each of the five brain regions

	Factors	Theta	Alpha	Beta	Gamma
Midline Correlations	Positive affect	.262**	.289**	.302**	.280**
	Negative affect	-0.049	-0.125	-0.101	-0.06
	Engagement	.273**	.318**	.323**	.299**
	Distress	-.219*	-.294**	-.271**	-.209*
	Worry	-0.131	-.225*	-0.123	-0.146
	Task_Focus	.317**	.336**	.347**	.272**
	Emotion_Focus	0.029	0.097	0.065	0.041
	Avoidance	-0.089	-0.09	-0.041	-0.112
LA Correlations	Positive affect	.234*	.271**	.301**	.275**
	Negative affect	-0.043	-0.118	-0.108	-0.07
	Engagement	.248**	.305**	.337**	.298**
	Distress	-.225*	-.304**	-.302**	-.239**
	Worry	-0.136	-.213*	-0.143	-.194*
	Task_Focus	.325**	.330**	.352**	.286**
	Emotion_Focus	0.06	0.096	0.076	0.081
	Avoidance	-0.096	-0.096	-0.093	-0.169
LP Correlations	Positive affect	.270**	.265**	.316**	.304**
	negative affect	-0.049	-0.117	-0.099	-0.015
	Engagement	.296**	.306**	.326**	.339**
	Distress	-.281**	-.322**	-.346**	-.288**
	Worry	-0.162	-.230*	-0.136	-0.173
	Task_Focus	.393**	.367**	.434**	.373**
	Emotion_Focus	0.108	0.167	0.122	0.114
	Avoidance	-0.08	-0.057	-0.003	-0.11
RA Correlations	Positive affect	.246**	.233*	.304**	.286**
	Negative affect	-0.038	-0.082	-0.086	-0.01
	Engagement	.280**	.282**	.338**	.286**
	Distress	-.255**	-.286**	-.302**	-.234*
	Worry	-0.109	-0.175	-0.135	-0.157
	Task_Focus	.345**	.337**	.388**	.329**
	Emotion_Focus	0.068	0.145	0.09	0.058
	Avoidance	-0.073	-0.047	-0.038	-0.071

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
RA: Right Anterior; LA: Left Anterior;
LP: Left Posterior; RP: Right Posterior

RP Correlations	Factors	Theta	Alpha	Beta	Gamma
	Positive affect	.246**	.233*	.304**	.286**
	Negative affect	-0.038	-0.082	-0.086	-0.01
	Engagement	.280**	.282**	.338**	.286**
	Distress	-.255**	-.286**	-.302**	-.234*
	Worry	-0.109	-0.175	-0.135	-0.157
	Task_Focus	.345**	.337**	.388**	.329**
	Emotion_Focus	0.068	0.145	0.09	0.058
	Avoidance	-0.073	-0.047	-0.038	-0.071

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
RA: Right Anterior; LA: Left Anterior;
LP: Left Posterior; RP: Right Posterior

Table 26. Verbal harassment study: channels that had shown significant in terms of EEG power (dB)

Freq	Channel Name	Source	Mean Square	F	Sig.	η_p^2
Theta	CPP3	Publicity * Social Interaction	30.84	4.806	0.037	0.146
Theta	PO4	Publicity * Social Interaction	39.524	4.713	0.039	0.144
Alpha	FCC1	Publicity	48.304	4.933	0.035	0.15
Beta	AF5h	Publicity	38.512	5.391	0.028	0.161
Beta	CPP4	Publicity * Social Interaction	28.785	5.894	0.022	0.174
Gamma	AF5h	Social Interaction	166.187	7.61	0.01	0.214
Gamma	AFF5	Social Interaction	95.088	5.737	0.024	0.17
Gamma	AFF5h	Social Interaction	42.432	4.712	0.039	0.144
Gamma	AFp3h	Social Interaction	106.717	5.953	0.021	0.175
Gamma	AFpz	Social Interaction	82.894	6.086	0.02	0.179
Gamma	CCP2	Social Interaction	10.201	5.044	0.033	0.153
Gamma	CCP5h	Social Interaction	14.443	5.953	0.021	0.175
Gamma	CPP3	Publicity * Social Interaction	14.992	4.483	0.043	0.138
Gamma	CPP5h	Social Interaction	12.943	4.278	0.048	0.133
Gamma	FCC2	Social Interaction	16.65	5.183	0.031	0.156
Gamma	FFC4	Social Interaction	28.012	5.126	0.032	0.155
Gamma	O1h	Social Interaction	26.416	5.167	0.031	0.156

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