Exploring the Impact of Motivational Arousal and Generalised Anxiety Disorder on Language Use

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Exploring the Impact of Motivational Arousal and Generalised Anxiety Disorder on Language Use

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Glossary

List of Acronyms

TPM	TU Delft Faculty of Technology, Policy, Management
TU Delft	Delft University of Technology
WHO	World Health Organization
HREC	Human Research and Ethics Committee
GAD	Generalized Anxiety Disorder
CBT	Cognitive Behavioral Therapy
iCBT	Internet Cognitive Behavioral Therapy
RCT	Randomized Controlled Trial
PANAS	Positive and Negative Affect Schedule
DSM	Diagnostic and Statistical Manual of Mental Disorders
ICD-10	International Classification of Diseases 10th Revision
GHS-MHS	German National Health Interview and Examination Survey, Mental Health Supplement
LIWC	Linguistic Inquiry and Word Count
EDA	Electrodermal Activity
SCL	Skin Conductance Level
SCR	Skin Conductance Response
IBI	Inter-Beat Interval
HR	Heart Rate
HRV	Heart Rate Variability
BVP	Blood Volume Pulse
BAS	Behavioral Approach System
BIS	Behavioral Inhibition System
PCA	Principal Components Analysis
EEG	Electroencephalogram

Abstract

Mental disorders are now becoming prevalent illnesses. More than 1 billion people globally were affected by mental and addictive disorders in 2016, which caused 7% of all global burden of disease (Rehm & Shield, 2019). Among those mental disorders, anxiety disorders and depression rank at the top. GAD is the most common anxiety disorder form in primary care, and the burden caused by GAD is severe in terms of decreased work productivity and increased health care utilization.

The present study pivoted around GAD, studying the intersection between motivational arousal, language, and sympathetic activation. A Randomized Controlled Trial (RCT) was designed and undertaken. The findings were satisfactory: Different arousal manipulation led to different language patterns of students. For example, negative (avoidance) arousal triggered fatigue-related words use. GAD inhibited motivational arousal effect on language, which extended the previous study that GAD people have 'diminished physiological flexibility'. Furthermore, sympathetic activation was observed during arousal manipulation, and the variability of Heart Rate (HR) and Heart Rate Variability (HRV) was significantly affected. Lastly, the 'diminished physiological flexibility' of GAD people was also shown in the present study: GAD students experienced little change in Electrodermal Activity (EDA), HR, and HRV under motivational arousal manipulation.

Executive Summary

Mental disorders are now becoming prevalent illnesses. More than 1 billion people globally were affected by mental and addictive disorders in 2016, which caused 7% of all global burden of disease (Rehm & Shield, 2019). Among those mental disorders, anxiety disorders and depression rank at the top. GAD is the most common anxiety disorder form in primary care, and the burden caused by GAD is severe in terms of decreased work productivity and increased health care utilization. One effective treatment is Cognitive Behavioral Therapy (CBT), the implementation of which has demonstrated the importance of language in expressing psychological states. The growing popularity of Internet Cognitive Behavioral Therapy (iCBT) suggests further directions for scientific exploration. In addition, as described in the Arousal Theory of Motivation, people are motivated to perform actions to meet optimal levels of physiological arousal (Charlotte, Nickerson, 2020), which makes it a critical part in psychological research.

There is limited GAD research on student populations. In recent years, more literature has revealed a gradual increase in the prevalence of GAD in student populations, which has caught the attention. The research objectives of this study were thus framed as exploring the intersection of motivational arousal, language, GAD, and sympathetic activation in the student population. The main research question was '*Do motivational arousal and GAD influence the language use of students?*'. A RCT was conducted, in which motivational arousal was the independent variable, the natural language was the dependent variable, GAD was the moderate variable, and sympathetic activation was the mediate variable (hypothesis shown in Figure 1-1).

In the experiment, GAD-7 scale was used to detect GAD with a total score of 10 (including 10) being a cut-point that divided the samples into an anxious group and a non-anxious group. Students were allowed to write about their anxious campus experience. Such a method originated from Pennebaker's (1997) study and was widely adopted in academia, known as the Expressive Writing Paradigm. Later, the language sample was digested by LIWC application which generated the usage frequency of word categories. For sympathetic activation, the Empatica E4 wristband helped to capture the physiological data; more specifically, we focused on HR and EDA. The two were said to be indicators of sympathetic activation.

The findings were inspirational as they answered the research question successfully and generated some unexpected results. Firstly, motivational arousal leads to different language use of students. Especially, 'fatigue', 'you', 'insight', 'cause' and 'moral' word categories showed

significant differences between the two arousal groups. We found out that non-GAD students used more second-person pronouns. In addition, the GAD inhibited the effect of the motivational arousal, which refers to a diminished response to the motivational arousal in terms of language use. Thirdly, the motivational arousal manipulation obviously triggers sympathetic activation in participants. HR and HRV variability of participants decreased by arousal manipulation. The EDA was reduced during the manipulation was an unexpected result. Lastly, again, GAD students presented inhibition of motivational arousal on sympathetic activation, which echoes the second finding and validates the previous studies. The main research question can be answered in this regard: the motivational arousal and GAD influence students' language use.

Beyond answering the research question, the present study contributed several directions for future work. In terms of the physiological part, focusing on HRV signals or introducing Electroencephalogram (EEG) would allow for a deeper study, with HRV representing sympathetic activation and EEG being able to detect GAD on a physiological level. Next, in terms of the psychological part, verbal language could be an exciting extension, as conversational chat is the primary method of CBT. People might have different language patterns when they speak and write. Furthermore, this study collected physiological data during narrative writing which were not investigated. Future research could focus on the physical effects of narrative writing, as narrative writing is also a standard tool in the treatment of mental disorders. Lastly, the general level and variation rate of skin temperature under motivational arousal in the present study showed a significant difference. Future research could focus on this signal and give a more scientific interpretation.

Acknowledgements

This acknowledgment is very long, but I urge you to read on; it is the best part of this project.

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Laurens already provided me with the best team. Can I tell you that Laurens led me to the topic? I was ignorant of the field of psychology. Laurens modified the research again and again – it was a tailor-made study and one-by-one teaching process, and TU Delft paid. Can I tell you that Laurens was explaining to me and taking notes for me at the same time in the beginning of the study? Just because his kid was slow to get into shape. Can I tell you how strict Laurens is for being so sweet? Laurens has frowned for two months: The literature review was revised six times to his satisfaction. Thank you, my angel!

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Delft, University of Technology Rui Yuan
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Chapter 1

Introduction

Mental disorders are now becoming prevalent illnesses. More than 1 billion people globally were affected by mental and addictive disorders in 2016, which caused 7% of all global burden of disease (Rehm & Shield, 2019). Among those mental disorders, anxiety disorders and depression rank at the top.

Generalized Anxiety Disorder (GAD) is the most common anxiety disorder form in primary care, characterized by excessive and uncontrollable anxiety and lasting at least six months. Commonly associated symptoms are substantial and enduring subjective suffering with few remission and the feeling of loss of control (APA, 2013). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM)-5 diagnosis criterion (APA, 2013), at least three physical symptoms are required: fatigue, restlessness, impaired concentration, or feeling as though the mind goes blank, irritability, sleep disturbance, and increased muscle aches or soreness. Children and youth are required to satisfy at least one of the physical symptoms.

Another feature of GAD is the high proportion of comorbidity with other disorders. One of the most extensive community epidemiological studies of GAD, the German National Health Interview and Examination Survey, Mental Health Supplement (GHS-MHS) suggested that 59% of cases have comorbid depression (Carter et al., 2001). It is worth mentioning that the impairment level associated with GAD is substantial. Even its pure form (without other comorbidities) is comparable to pure depression regarding the impairment in social functioning and work productivity of individuals (Kessler et al., 2001; Hoffman et al., 2008; Henning et al., 2007). Besides, evidence showed that people with GAD were frequent users of primary care resources. A twofold higher number of visits to primary care doctors for GAD cases compared to depression cases was reported (Wittchen et al., 2002).

In conclusion, the burden caused by GAD is severe in terms of decreased work productivity and increased health care utilization. Nevertheless, it is said that most people with GAD can only be diagnosed and effectively treated after carrying the symptoms for 5 to 10 years (Ballenger et al., 2001; Kessler et al., 2001; Rogers et al., 1999). Moreover, only 61% of these people received evidence-based treatment (NPS Medicinewise, 2022). Two reasons contribute to this fact. The symptoms of GAD are inclined to be neglected and be treated as stress,

especially under highly stressful working conditions. Other than that, clinical therapists could not confidently identify it because the diagnostic criteria for GAD are immature and deficient (Starcevic, 2015), and most GP do not possess comprehensive psychological knowledge.

Cognitive Behavioral Therapy (CBT), driven by conversation (Barnes et al., 2012), is widely accepted as an effective and dominant treatment for GAD. Most CBT programs for GAD include relaxation training to relieve somatic symptoms and cognitive therapies to deal with worry-related thoughts (Barlow, 2021). A large body of studies has verified the efficacy of CBT for GAD (Scogin et al., 1992; Kendall, 1994; Gould et al., 1997; Becker et al., 2011; Reynolds et al., 2012). The popularity of CBT treatment verified the link between mental status and language, however, limited studies work on the language pattern and GAD. At the same time, Internet Cognitive Behavioral Therapy (iCBT), facilitated by Internet technology, has proved efficacy both in research findings and primary care settings. (Christensen et al., 2009; Titov et al., 2009; Andrews et al., 2010; Griffiths et al., 2010; Robinson et al., 2010; Mewton et al., 2012; Carl et al., 2020; Trenoska Basile et al., 2022). These studies indicate that iCBT (online CBT applications) for GAD is an efficacious and acceptable treatment that requires minimal therapist involvement and lower cost (Mewton et al., 2012). The efficacy of iCBT confirmed the strong linkage between written-text and GAD. This fact suggests the possibility and feasibility of further exploiting Internet applications' potential in GAD diagnosis and treatment. In such a setting, the free text will play a dominant role in leading the treatment process. Nevertheless, studies in this domain are very limited.

As an exception, Lyons et al. (2018) once studied the correlation between mental distress and language use and found that mentally distressed people were inclined to use singular personal pronouns and negative emotion words. In contrast, situational stress refers to a short-term form of stress that occurs in certain temporary situations (North Central Behavioral Health Systems, 2022). An interesting experiment conducted by Sorg & Whitney (1992) examined the performance of a reading task among high and low trait anxiety people when they were exposed to a stressful environment. There were interactive effects of trait anxiety and situational stress on reading performance. The performance of the high anxiety subjects decreased in the stressful condition. Anxiety conditioning is a type of arousal, which is a state of physiological activation or cortical responsiveness associated with sensory stimulation and activation of fibers from the reticular activating system (APA, 2022a). In fact, motivational arousal is an essential term in the psychological research field. The famous Arousal Theory of Motivation indicates that people are driven to perform actions in order to maintain an optimum level of physiological arousal (Charlotte, Nickerson, 2020). Motivational arousal links a person's psychological and physical states and is therefore of great interest.

1-1 Problem Definition

GAD has been one of the most prevalent mental disorders worldwide in the past two decades. It is said that female is more inclined to be affected by GAD than men, and prevalence is high in midlife (Wittchen, 2002). However, the prevalence was calculated with a great bias, and young adults show a comparable risk of getting GAD after modifying the grouping bias. Currently, most GAD-related studies focus on either children and adolescents (Mohammadi et al., 2020; Costello et al., 2005) or mid-age and older people (Goncalves & Byrne, 2012; Stanley & Novy, 2000). Few studies focus on young adults aged between 18 and 30 due to its lowest

prevalence among all age groups. However, 38.73% students were suggested to have GAD (Rook et al., 2022), which holds the most up-to-date findings. 63% of students were classified as having high state anxiety in a study conducted at the University of Sharjah (Otim et al., 2021). College students are vulnerable to anxiety problems due to their rapid psychological and stressful study life. Most students cannot access the treatment in time because of several factors. It is confirmed the high prevalence of GAD in youth and the young adult group from the general population (Beesdo-Baum et al., 2019, 2011). Two third of people with mental problems cannot access a clinical consultation in a short period because of a long waiting list (Hunt & Eisenberg, 2010). The fear of being judged is another crucial factor that prevents them from seeking external help (Chandra & Minkovitz, 2007; Fitzpatrick et al., 2017) while the impairment is considerable both in individual and social aspects as described in chapter 1. In conclusion, college students are also experiencing substantial anxiety disorders and insufficient clinic resources. However, few studies focus on this group.

1-2 Research Objective

The main objective of the present study is to analyze the intersection of four different disciplines concerning GAD, sympathetic activation, motivational arousal, and natural language. The dominant aim is to explore if and how a student's GAD can be recognized from their text given different levels of motivational arousal.

1-3 Research Question

The following research question is proposed based on the problem definition and research objective, as shown in Figure 1-1.

Main Research Question: *Do motivational arousal and GAD influence the language use of students?*

The main research question incorporates three dimensions: GAD, motivational arousal level, and natural language. To investigate the mutual correlations between the three factors is imperative for understanding the mechanism between the mental status, language expressions of students, and external environment (external stress stimulus). Focus on the college students group grants this study great social and economic potential and benefits.

To deal with the main research question, the following sub-questions are raised.

Sub-question 1: *Does motivational arousal lead to different language use of students?*

The first sub-question investigates the relationship between motivational arousal levels and different language patterns.

Sub-question 2: *Does GAD influence the language use of students, given certain motivational arousal?*

The second sub-question is used to examine if GAD will impact students' language expressions.

Sub-question 3: *To what extent does the motivational arousal writing manipulation trigger sympathetic activation in students?*

The third question is an exploratory question, aiming to test if sympathetic activation is triggered when students are exerted certain levels of motivational arousal.

Sub-question 4: *To what extent do students with a high score on GAD differ in terms of sympathetic activation from participants with a low score on GAD?*

The fourth question is a follow-up exploratory question. This question intends to explore if GAD students will behave differently during the experiment if the third question is confirmed with a high correlation. More specifically, students with high GAD score will show different sympathetic activation patterns than students with low GAD score when they are given some motivational arousal and are invited to do a writing task.

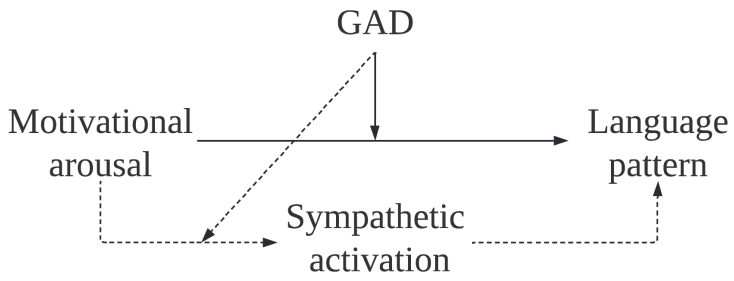

Figure 1-1: Hypothesis of the Study

1-4 Project Structure

This project contains five chapters. The chapter 1 is an introduction that describes the research problem, objective, and research questions of this study. You can tell the significance of this study from the introduction. The chapter 2 is a literature review with studies on mental disorders, GAD, arousal and language, and psychophysiology reviewed. The chapter 3 documents the research methods, including the participants, the experimental procedure, materials, instruments, and scales. The chapter 4 records the results of the experiment, and interesting findings are documented. The final chapter 5 discussed, for example, the scientific relevance, the practical relevance of the finding, and the limitations of this study.

Chapter 2

Literature Review

In this chapter, mental disorders, Generalized Anxiety Disorder (GAD), sympathetic activation, and language-related studies were revisited.

2-1 Mental Disorders in General

Mental disorders commonly refer to two diagnostic types: depressive disorders and anxiety disorders, which are estimated to afflict 4.4% of the global population with depression disorder and 3.6% with anxiety disorder in 2015 (Organization, 2017). Mental disorders are becoming prevalent illnesses. More than 1 billion people globally were affected by mental and addictive disorders in 2016, which caused 7% of the global burden of disease (Rehm & Shield, 2019). Mental disorders are diagnosable and are distinct from the stated negative feelings such as sadness, stress, or fear that anyone can experience according to the World Health Organization (WHO) (Organization, 2017). In 2001, WHO predicted that mental disorders were expected to be the second leading cause of the global disease burden by 2020. The prediction has probably been accelerated. After all, the number of cases with psychological disorders tripled during Covid (Ettman et al., 2020). Psychological problems are inclined to be ignored by patients and families in the early phase (Greden, 2003), causing them to miss the best treatment time and leading to severe consequences.

On the other hand, mental health professional shortage is never a short-term problem. Over three-quarters, (77%) of U.S. counties had a severe shortage of mental health professionals, with over half of their needs unmet (Thomas et al., 2009). The shortage in the psychiatry workforce in 2017 was 6.4%, a deficit of 12% was predicted by 2025 across the United States (Levin, 2017). Anxiety disorder, one of the most common mental disorders, is understood as the overall human reaction to a dangerous situation with activated psychological alarms (Moss et al., 2003). Anxiety is an appropriate feeling when people encounter a stressful situation. Such anxiety is normally short-lived and disappeared automatically. In contrast, anxiety becomes a mental disorder when it is out of control; and anxiety disorders are persistent and worsen over time (National Institute of Mental Health, 2022a). 40 million American

adults aged 18 and older each year were affected by anxiety disorders, equivalent to 18.1% population (Anxiety & Depression, Association of America, 2022). Approximately 3.6%, or 264 million people around the world, suffered from anxiety disorders (Megan Hull, 2022). An estimated 31.1% of U.S. adults experience anxiety disorders at some time in their lives (National Institute of Mental Health, 2022b). Only 36.9% of patients are reported to receive treatment.

In a study conducted among German, adolescents and young adults aged between 14 and 24 (Wittchen et al., 1998), two third of participants were students. Results showed that the lifetime prevalence of anxiety disorder was 14.4%. If sub-threshold was included, the anxiety disorders would rank at the top as 26.7%. Another finding was that 58% GAD candidates would seek external help, and all of them went to physicians instead of psychiatrists. People with anxiety disorders are three to five times more likely to seek medical attention than those without anxiety disorders (Anxiety & Depression, Association of America, 2022).

According to National Institute of Mental Health (2022), an estimated 22.8% of anxiety-disordered patients experience severe impairment, and 33.7% have a moderate impairment. The prevalence of any anxiety disorders is higher for females than for males. Patients are afflicted by extreme and lasting anxiety for a specific topic, for instance, agoraphobia, Obsessive-Compulsive Disorder (OCD), panic disorder, and Post-traumatic stress disorder (PTSD) (Erica Cirino, 2018). The GAD ranks top as the most prevalent anxiety disorders (Davidson & Dugar, 2010).

2-2 Generalized Anxiety Disorder (GAD)

People with GAD display excessive and uncontrollable anxiety or worry, lasting for at least 6 months (Annals of Internal Medicine, 2022). GAD is the most common anxiety disorder form in primary care (Davidson & Dugar, 2010). 6.8 million adults or 3.1% of the U.S. population were affected by GAD, with only 43.2% receiving treatment (Anxiety & Depression, Association of America, 2022). Patients with GAD constantly and repeatedly worry about ordinary events, with the symptoms of feeling restless, being easily fatigued and irritable, having difficulty concentrating, and having sleep problems (APA, 2013). Another feature of GAD is the high proportion of comorbidity with other mental disorders. 59% of cases had comorbid depression as was stated (Carter et al., 2001). It is worth mentioning that the impairment level associated with GAD is substantial. Even its pure form (without other comorbidities) is comparable to pure depression regarding the impairment in social functioning and work productivity of individuals (Kessler et al., 2001; Hoffman et al., 2008; Henning et al., 2007).

The prevalence of GAD has been reported to be approximately twice as high in women as in men (Alonso et al., 2004; Wittchen, 2002; Davidson & Dugar, 2010). A large-scale community survey conducted in Shatin, Hong Kong suggested a higher GAD prevalence rate among females (11.1%) than males (7.8%) (Chen et al., 1993). 7,229 candidates participated in this survey, aged between 18 and 64. The one-year prevalence of GAD survey conducted by Carter et al. (2001) demonstrated the same result that female is more likely to have anxiety disorders than male among all age categories.

2-2-1 GAD Diagnosis

Given the prevalence and impairment associated with GAD, accurate diagnosis is critical. Diagnostic and Statistical Manual of Mental Disorders (DSM) iterations, which are widely accepted diagnostic instruments, were developed by American Psychiatric Association.

Until the publication of DSM-III, the GAD was referred as 'pantophobia' or 'anxiety neurosis' (Crocq, 2022). The GAD was described as 'generalized and persistent anxiety of at least 1-month duration' in DSM-III (APA, 1980). 'Excessive anxiety' became a keyword and the required duration increased to 6 months in 1987 edited DSM-III-R. The DSM-IV became standard for all age groups, and previous diagnosis criteria for youth were eliminated. Furthermore, experiencing 'excessive' and 'uncontrollable' worry across an unspecified number of areas for 6 months or longer, and at least one physiological symptom were key statements (APA, 1994). One of two retained symptoms (restlessness or muscle tension) must be present for GAD definition in the DSM-5 (APA, 2013).

Another criteria: the International Classification of Diseases 10th Revision (ICD-10), was developed by WHO in 1993, has been proven the same effectiveness as DSM-IV (Slade & Andrews, 2001; Maier et al., 2000). The newest version ICD-11 officially came into effect in 2022 and 35 countries have adopted it (WHO, 2022). Anxiety and Fear-Related Disorders share non-specific physiological arousal with sympathetic autonomic activation and behavioral changes (WHO, 2022). Furthermore, the GAD is characterized by general apprehensiveness or worry that is not restricted to any particular stimulus, accompanying muscle tension and autonomic over-activity (Reed et al., 2019). Contrary to ICD-10, GAD can co-occur with depression as long as symptoms are present independent of mood episodes in ICD-11. Notably, ICD-11 relaxes the required duration of GAD symptoms by replacing a specific time interval (6 months) with 'several months' (El Khoury et al., 2020).

2-2-2 GAD and Students

Most general population surveys (Wittchen et al., 1994; Faravelli et al., 1989; Chen et al., 1993) confirmed that the 12-month prevalence of GAD ranged from 1.1-3.6% in adults. The lifetime rate was higher, with an estimated range from 4.1-6.6% (Carter et al., 2001). It was found that there is a lower prevalence rate in adolescents and young adults (Wittchen et al., 1998). However, it is interesting that age groups were set in different ranges when comparing the prevalence rate in the metadata. The 18-34 age group was compared with the 35-65-year-old group, which caused a double age gap between the two groups; After modifying the age set, the prevalence in young adults was comparable to that in old. Furthermore, the sample size is another source of bias, as 51 adolescents and young adults were compared with 145 mid-aged adults in Carter et al.'s study (2001, data was from German National Health Interview and Examination Survey, Mental Health Supplement (GHS-MHS)). In many aspects, the performance of GAD among all ages is the same, given the same diagnosis are adopted.

GAD is one of the most prevalent mental disorders in school. 63% of students were classified as having high state anxiety in a study conducted at the University of Sharjah (Otim et al., 2021). The incubation period of GAD is long (Greden, 2003). Mental disorders such as phobic disorder start to emerge in childhood while others, major depression and GAD emerge later in adolescence (Wittchen, 1996; Wittchen et al., 1998). This may be a contributor to

the low prevalence rate among young adults as GAD is latent in this period for most people and, thus, could not be diagnosed.

2-3 Arousal & Natural Language

This section reviewed studies related to natural language, affect, and arousal, as well as the natural language process software: Linguistic Inquiry and Word Count (LIWC).

2-3-1 Language and LIWC

The words people use can provide rich information about their beliefs, moods, social relationships, and personalities. Researchers have accumulated increasingly convincing evidence that the words people use have immense psychological value (Pennebaker et al., 2003; Gottschalk & Gleser, 1979; Stone et al., 1966).

The study dates back to 1901 when Austrian neurologist Freud et al. (1978) made the first conjecture that the common mistakes people make in speech mirrored their fears, doubts, and deeper motivations. Language is a mirror of mental states and does not appear to be questioned. Furthermore, it has been confirmed that writing emotional experiences and talking (e.g., in a Cognitive Behavioral Therapy (CBT) setting) shared comparable therapeutic effects regarding biological indicators, mood, and cognition (Pennebaker, 1997). Interestingly, students were once asked to express a traumatic experience using bodily language and then to write it down and compared to those assigned to do some exercise (Krantz & Pennebaker, 1996). The result indicated that mere expression was insufficient, and health gains appeared to require translating experiences into language.

Nevertheless, the study of language patterns is time-consuming and labor-intensive, and it was extremely difficult to classify and combine language patterns manually. Later, the analytical LIWC computer program was developed by Pennebaker's team in 1991. The program was designed to analyze essays in text format, and the initial version has four categories: negative emotion words (e.g., sad, upset), positive emotion words (e.g., happy, glad), causal words (e.g., because, reason), and insight words (e.g., understand, realize) (Pennebaker, 1997). When the text is entered, LIWC is able to quickly calculate the percentage of these categories so that the language pattern of the individual and his/her mental state can be inferred. The findings suggested that narrative format was fundamental and could be seen as an indicator of mental and physical well-being (Pennebaker & Seagal, 1999).

Most mental disorder research was facilitated by the LIWC2015 (Pennebaker et al., 2001) version (LIWC-22 is in service). It was discovered that GAD people used much more personal pronouns and affective words than the control group. More specifically, people with GAD were reported to use more first-person singular pronouns, but fewer first-person plural pronouns than the control group. Negative emotion word usage was significantly higher in the GAD group, especially anxiety words (Lyons et al., 2018). Another interesting experiment, in which students with social anxiety disorder and normal students were asked to give public speeches, was performed in 2012; as a result, students with psychological disorders were more inclined to use negative expressions (Hofmann et al., 2012).

2-3-2 Motivational Arousal and Language

Feldman Barrett & Russell (1998) once defined words based on arousal level and classified them into activated and deactivated word categories. Later research suggested that negative stimulus elicited slower responses than neutral stimulus in a range of cognitive tasks (Fox et al., 2001; Kuperman et al., 2014). For example, the negative word *coffin* tended to evoke slower lexical decisions (Wentura et al., 2000), and slower word naming (Algom et al., 2004) than the neutral word *cotton*. Furthermore, arousal has been proven in word recognition speed (Estes & Adelman, 2008). For example, negative words (e.g., 'shark') typically elicit slower color naming, word naming, and lexical decisions than neutral or positive words (e.g., 'beach'). Exciting words were recognized faster than other words. Other than that, it has been shown that understanding action words (as external stimuli) affects arousal level and activates approach and avoidance motor processes (Claus & Bader, 2008). The neural system activation was found to have a strong correlation with verbal approach/avoiding descriptions of everyday actions. When people read approach/avoidance action sentences, their neural systems can be detected to having representative electrophysiological activities (Marrero et al., 2017). Such research acknowledged that language can play a key role in arousal activation.

Zajenkowski (2013) suggested that external stimuli (e.g., noise) greatly affected the performance of complex text processing tasks. Another interesting study proposed that the arousal state was a key factor in the speech perception process (Schuerman et al., 2022). Recently, (Al-Khatib & Fletcher, 2019) (2019) confirmed the different arousal levels in the native language and another second language.

2-4 Physical Performance and Mental Disorders

Autonomic nervous activities especially sympathetic activation associated with anxiety disorders-related research were studied in this section.

2-4-1 Autonomic Nervous Activities and Affect

Many generally acknowledged cases surface the interaction between human physical and mental states. For example, the heart beats faster when speaking in public, stress may affect sleep, and aerobic exercise facilitates mental health. In many recent theories of emotion, autonomic nervous system activities are primary components of emotional responses (Kreibig, 2010). The autonomic nervous system regulates involuntary physiological processes, also known as physiological arousals, such as heart rate, blood pressure, respiration, digestion, and sexual arousal (White et al., 1952; Waxenbaum et al., 2019). The sympathetic nervous system, parasympathetic nervous system, and enteric nervous system comprise the autonomic nervous system. The sympathetic nervous system enables the body to manage stressors by regulating blood vessels. In most cases, sympathetic activation leads to vasoconstriction and heart rate increasing, while vasodilation is the opposite. Thus, sympathetic activation is seen as a cardinal biological characteristic of fear (Roth et al., 2008). Furthermore, it is noted from laboratory studies that physiological signals such as Electrodermal Activity (EDA) and heart rate can map psychological distress (Nock & Mendes, 2008; Lazarus et al., 1962). Specifically,

Heart Rate Variability (HRV) and EDA, as two of the most prominent indicators of sympathetic activation (Roth et al., 2008), are commonly prescribed indicators in assessing anxiety (Croft et al., 2004; Henje Blom et al., 2010).

Affect, which refers to any experience of feeling or emotion, is often described as positive or negative affect (APA, 2022b). In psychology, affect regulates and facilitates the interaction between organisms and stimuli. Positive and Negative Affect Schedule (PANAS) (Watson et al., 1988) is one of the most prestigious affect scales, which was developed based on the Zevon & Tellegen's (1982) mood checklist. The scale incorporates 20 items; 10 items are used to measure positive affect (e.g., happiness), and the other 10 items measure negative affect (e.g., anxiety). The PANAS mirror the personality dimensions, with high NA reflecting subjective distress and unpleasant involvement; high-NA subjects are more likely to experience discomfort at all times and across situations, even in the absence of overt stress (Watson & Clark, 1984). By contrast, the PA schedule measures the extent to which individuals engage in a pleasant environment. Thus, PANAS measures the tendencies to experience positive and negative effects. Watson et al. (1999) argues that PA and NA represent the subjective components of broader approach behaviors and withdrawal behaviors, respectively. Furthermore, PANAS effectively differentiates between depression and anxiety (Watson et al., 1995a,b; Dyck et al., 1994; Gellman, 2020). This statement is derived from the Tripartite Model of Anxiety and Depression. The Tripartite model posits that depression and anxiety can be differentiated effectively and physiological hyperarousal is a unique characteristic of anxiety (Clark & Watson, 1991).

2-4-2 Sympathetic Activation and GAD

Hyperarousal symptoms are often complained by individuals with GAD (Roth et al., 2008; Thayer et al., 1996), such as feeling keyed up, muscle tension, and insomnia. Seeking cardiologic evaluation for sympathetic nervous symptoms (e.g., increased heart rate and shortness of breath) is quite common of GAD patients (Logue et al., 1993). Indeed, differences in cardiopulmonary responses between GAD subjects and controls at baseline, during relaxation, and under stress were confirmed, and GAD patients exhibited shorter interbeat intervals (IBIs) (Thayer et al., 1996). Later, similar patterns were examined (Brosschot et al., 2006). Hoehn-Saric et al. (1989) once found the reduced heart period range and skin conductance responses in GAD patients. Diminished variability in skin conductance response associated with anxiety was validated by Lader & Wing (1964). Thus, patients with GAD were posited to have 'diminished physiological flexibility' with a smaller physiological response to stressors compared to non-anxious people (Hoehn-Saric et al., 1989). In contrast, non-anxious people showed faster recovery under stress. Later, Hoehn-Saric et al. (2004) proposed that patients with chronic anxiety disorder exhibit physiological over-stimulation at rest or enhanced physiological response to stressors (Roth et al., 2008). Thayer et al. (1996) pointed out that patients with GAD exhibited increased heart rate under mental stress.

2-5 BIS/BAS

The Behavioral Inhibition System (BIS)/Behavioral Approach System (BAS) personality theory is a critical component in this domain, thus, it was reviewed in this section.

The Behavioral Inhibition System (BIS) and the Behavioral Approach System (BAS) are two of the most fundamental concepts of motivation theories. (Gray, 1987, 1990). The BIS/BAS personality theory holds that there are two major biological mechanisms that regulate and control human effects and behaviors. The BAS mediates approach behavior to potentially rewarding stimuli or relief from punishment, leading people to engage in convergent behavior and experience positive emotions, such as pleasure and excitement (Depue & Collins, 1999; Lang et al., 1990). In contrast, BIS (also known as anxiety system) is sensitive to punishment stimuli, inhibits or interrupts ongoing behavior in response to punishment cues (passive avoidance); and in most cases, accompanied by negative emotions, such as anxiety and fear (Lang et al., 1990; Gray, 1987). Notwithstanding, the primary function of BAS is approach motivation, which may also associate with negative emotions. As Carver (2001) reviewed, sadness emerged when individuals failed to achieve approach-oriented goals. Furthermore, BIS and BAS sensitivity differences of individuals were proposed to account for personality differences: BAS correlates 'Impulsivity' dimension, and BIS is linked to 'Anxiety' dimension (i.e., tendency to feel anxiety) (Gray, 1970). Overall, BIS is an avoidance arousal system while BAS is an approach arousal system. Extensive research revealed that heart rate was strongly tied to the BAS activity and EDA would increase when the BIS is activated (Fowles, 1980).

The 'Affect arousal' is an intrinsic term in motivation studies, which refers to the state of being physically or psychologically activated due to an emotional stimulus (Niven & Miles, 2012). The renowned Arousal Theory states that the physical environment can affect arousal levels by stimulation and by the stress created when psychological or physical needs are not met (APA, 2022c). At the same time, the Arousal Theory of Motivation, firstly proposed by Henry Murray in 1938, indicates that people are motivated to perform actions in order to maintain an optimal level of arousal. In conclusion, external stimuli affect an individual's arousal level, making it higher or lower than the optimal threshold; The BIS/BAS then drives actions to achieve the optimal arousal state. Subsequently, many scholars have been involved in the design of the BIS/BAS scales. Among which, the BIS/BAS scales compiled by Carver & White (1994) were widely adopted. Lastly, The BIS is strongly correlated to NA while BAS is related to PA (Carver & White, 1994). Therefore, PANAS can serve as a reliability control of BIS/BAS scales. And vice versa.

In conclusion, individual differences in BIS/BAS sensitivity influence not only approach/avoidance behaviors but also sympathetic activation associated with external emotional arousal stimulus. As such, it is essential to investigate people's BIS/BAS sensitivity when studying psychological and physical features of GAD.

Chapter 3

Research Methods

A Randomized Controlled Trial (RCT) will be designed and conducted to answer the research questions. In a RCT, individuals are randomly divided into a control group and an experiment group according to different experimental conditions. In the present study, two different levels of motivational arousal will be included, an approach and avoidance arousal, respectively. The approaching arousal group is the control group (is hereinafter referred to as the approaching group) while the avoidance arousal group (is hereinafter referred to as the avoidance group) is the experiment group.

3-1 Ethics Approval

The research was approved by the Human Research and Ethics Committee (HREC) of the Delft University of Technology (TU Delft). All experiment participants voluntarily partook in this study. The data management plan designed for the study was confirmed by the TU Delft data steward. The entire experiment was conducted in paper-and-pencil format, and the experimental data collection was entirely separate from personal data collection.

3-2 Participants

Participants were randomly assigned to the experimental conditions of motivational arousal (approaching or avoidance) factorial design, and the Generalized Anxiety Disorder (GAD) was added as a covariate. The initial sample consisted of 66 college students including undergraduates, Master's students and PhDs (35 men and 31 women; M_{age} = 24.42 years, SD = 2.3). It was made clear from the outset that all experimental sessions should be finished and the generated data would be used for the present research. In the end, 7 participants did not follow the instructions, thus, their data was removed. As a result, the sample size was 59 (32 men and 27 women; M_{age} = 24.42 years, SD = 2.38). This sample was used for further analyses.

3-3 Procedure and Materials

The procedure was as follows (also displayed in Figure 3-1): Participants received an invitation to the 45-minute study through social media with a short description and a register link, which was forwarded to a shared Excel form. Participants could check the available experiment time slots, and contact the instructor to confirm the time and experiment location. 68 volunteers registered, of which 66 participated in the experiment on time. Volunteers were invited to the TU Delft Faculty of Technology, Policy, Management (TPM) Laboratory, signing the written informed consent before putting on the testing equipment (Empatica E4 wristband, see below). Ten minutes were spent explaining the whole experiment procedure, while the wristband captured the baseline data. After that, the volunteer received a booklet and was asked to finish the booklet according to the given instructions. The first part of the booklet assessed the Behavioral Inhibition System (BIS)/Behavioral Approach System (BAS) and GAD-7 scale, the tendency to be anxious and anxiety severe level of the participants. The second part of the booklet contained the approaching-avoidance manipulation disguised as an exercise in perspective taking (see below). A 12-item mood testing followed. After that, participants were invited to write down anxious moments in their campus life. In the end, the physically traced data were saved, and the equipment was taken off, marking the ending of a single case.

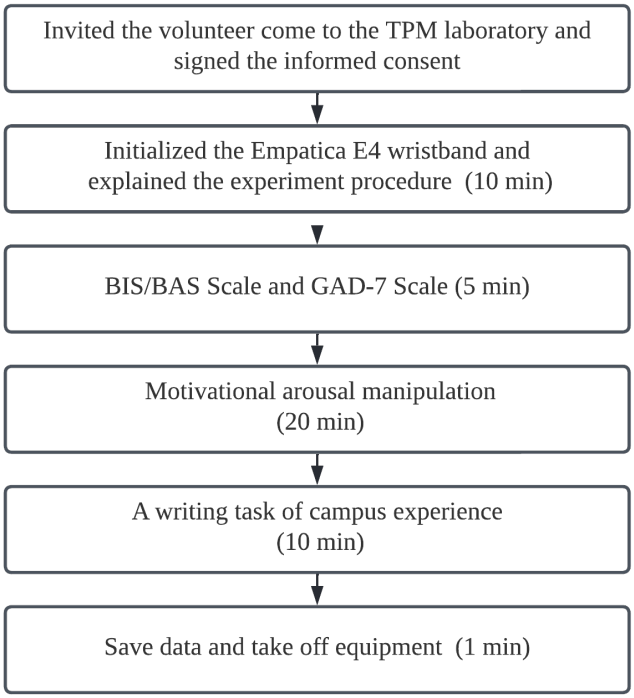

Figure 3-1: The Experiment Procedure

3-3-1 Motivational Arousal

In the present study, motivational arousal level is the independent variable. Motivational arousal normally incorporates approaching and avoidance arousal. Friedman & Förster (2005) introduced a paradigm (hereinafter referred to as mouse maze treatment) in which approaching (or avoidance) motivation was elicited by providing participants with a pencil-and-paper picture of a maze and a mouse and asking them to find a way out of the maze before writing a vivid story. The mouse was located in the center of this maze. In the approaching condition, a piece of cheese was depicted outside the maze exit and represented as a reward (i.e., the mouse's favorite food). Participants had to find a path directing to the exit, and get the cheese, which triggered the approaching motive. In the avoidance condition, a cartoon owl was drawn outside the maze, which was seen as a punishment (i.e., an owl is the mouse's natural enemy). This setting was avoidance arousal. The treatment was proved to be sufficient to trigger approaching/avoidance motivation (Friedman & Förster, 2005; Rook, 2014). Moreover, thanks to the experimental process, participants found it exciting and were inclined to get immersed. The beauty of the latter setting and instruction is that it is ostensibly unrelated to the conscious affective experience.

After finishing the maze, participants were invited to write a vivid story from the perspective of the mouse, given the two motivational arousal levels. For the approaching group, the original story title was defined as 'The Happiest Day of the Mouse' (Friedman & Förster, 2005) and was replaced with 'A Happy Day in the Life of the Mouse' (Rook, 2014). While under the avoidance condition, the story title 'A Terrible Day in the Life of the Mouse' was used. The variation was more subtle, thus, triggered motivational arousal but did not evoke extreme effect (happiness and/or anxiety).

3-3-2 Language and Disclosure Writing

The Expressive Writing Paradigm was developed and widely used in laboratories when exploring the value of language about emotional experiences. The writing paradigm, also known as disclosure writing, was found powerful in investigating people's deepest thoughts. Participants were allowed to write about their deepest thoughts and feelings about an important emotional issue in their life for 3 to 5 consecutive days, and write on whatever topics they wanted (Pennebaker, 1997). According to Pennebaker (1997), participants disclosed an impressive range and depth of traumatic experiences, such as lost lovers, deaths, and physical abuse. These writing tasks were subsequently demonstrated to be beneficial in improving mental health. Thus, in this study, the self-narrative writing task (modification of the Expressive Writing Paradigm) was chosen as a measurement of the language of participants. Participants were invited to write a piece of their anxious experience in their campus life, with the freedom to express their deepest thoughts and feelings about the issue. There was a minimum 100 words restriction. Linguistic Inquiry and Word Count (LIWC) facilitated language patterns recognition. The average word count of the 59 valid data was 327 (std. = 169.07).

3-4 Equipment

The physiological signs of sympathetic activation are a dominant biological feature of fear (Roth et al., 2008). In the DSM-5 definition, patients with GAD should show signs of sympathetic activation. Skin conductance and heart rate are the two most common experimental indicators of sympathetic activation (Obrist, 2012). Thus, equipment capturing the heart rate and skin conductance-related data is needed.

The Empatica E4 wristband (as shown in Figure 3-2), developed by Empatica Inc., is widely adopted in scientific research thanks to its precise measurement of bodily real-time tracing data (Empatica Inc., 2020). Empatica E4 wristband was used in a foreign language education anxiety study, help to capture sympathetic activation (Rivers, 2022). Actually, the wristband has been adopted in many academic research, such as in sickness detection (Martin et al., 2020), stimulation detection (Cosoli et al., 2021) and stress detection (Siirtola & Röning, 2020).

The E4 wristband is a remote, medical-grade patient monitor device with excellent reliability. The wristband collects three kinds of data (as displayed in Table 3-1), they are Electrodermal Activity (EDA), Blood Volume Pulse (BVP), and skin temperature. The Inter-Beat Interval (IBI), Heart Rate (HR), and Heart Rate Variability (HRV) are derived from BVP, helped by advanced algorithms. The EDA measures sympathetic nervous system arousal and reflects stress engagement (Empatica Inc., 2020). Empatica E4 wristband captures both tonic level and phasic level EDA, known as Skin Conductance Level (SCL) and Skin Conductance Response (SCR). In addition, the wristband has an 'event' button, which can be used to record a series of pre-specified events. Such as 'the writing task is starting'; 'feel anxious and stressed at the moment'; or 'the writing task is finished'. Thus, the 'event' function can divide the continuously physical data into different experiment phases. It is recommended to wear the wristband on the non-dominant wrist to minimize motion artifacts (Picard et al., 2016), and have a 15-minute baseline record before experiment (Support Empatica, 2021).

3-5 Measures

This section describes the measurement manipulation and self-reported questionnaires.

3-5-1 GAD-7 Scale

The GAD-7 scale was employed to determine the GAD level of participants. GAD-7, as a standard 7-item measurement, is typically used in outpatient and primary care settings to assess the anxiety level of patients (Löwe et al., 2008). GAD-7 is a sensitive and efficient self-reported instrument for recognizing GAD developed by Spitzer et al. (2006). There are seven items, using a 3-point Likert scale. The questions investigate how often the candidates have been bothered by inquiry items over the past two weeks. Sample items are "Feel nervous, anxious or on edge" and "Worrying too much about different things". Point 0 represents 'Not at all', and point 3 represents 'Nearly every day'. The sum of scores of 7 items will yield the overall anxiety level. The higher the score, the more severe the participant suffers from GAD, and the maximum score is 21. GAD-7 scale was initially validated in a primary

Sensor	Data	Description	Sampling Rate
Photoplethysmography (PPG)	IBI	The time interval between individual beats of the heart. It's used to estimate the instantaneous heart rate.	-
	HR	The average heart rate values computed in spans of 10 seconds.	1 Hz
	HRV	where the amount of time between heartbeats fluctuates	-
Galvanic Skin Response (GSR)	SCR/SCL	The tonic- and phasic-level electrical conductance across the skin, showing general as well as fast-changing elements of the signal.	4 Hz
Infrared thermopile	Temperature	skin temperature in degrees on the Celsius	4 Hz

Table 3-1: Empatica E4 Function

care sample. Sensitivity and specificity exceeded 0.80 at a cut point of 10 or greater, and sensitivity was almost maximal. The majority of patients with GAD (89%) had a GAD-7 score of 10 or higher, while the majority of patients without GAD (82%) had a score of less than 10 (Spitzer et al., 2006). Thus, it is widely accepted that 10 points are the watershed for identifying GAD. In the present study, 20 participants scored equal to or greater than 10, meaning 33.9% of students could be identified as high on GAD (Cronbach's $\alpha = .90$, the internal consistency reliability of the scale is very good).

3-5-2 BAS/BIS Scale

The Carver & White (1994) BAS/BIS questionnaire was used to assess the BAS/BIS individual sensitivity. The BIS scale consists of seven items, with sample items such as "I worry about making mistakes" and "I have very few fears compared to my friends". The latter being reverse scored. The BAS scale consists of three subscales: reward responsiveness, drive, and fun-seeking. Sample questions such as "It would excite me to win a contest", "I go out of my way to get things I want", and "I crave excitement and new sensations", correspond to the three subscales, respectively. The three subscales are joined to form the BAS index because of significant correlations between subscales (r's > 0.28, Ps < 0.001). The BAS/BIS scale uses a four-point scale (1 = strongly disagree to 4 = strongly agree). The overall score was computed after reverse coding the respective items. In this study, the internal consistency reliability of the scale is acceptable (Cronbach α were: BIS (.82), BAS (.78)).

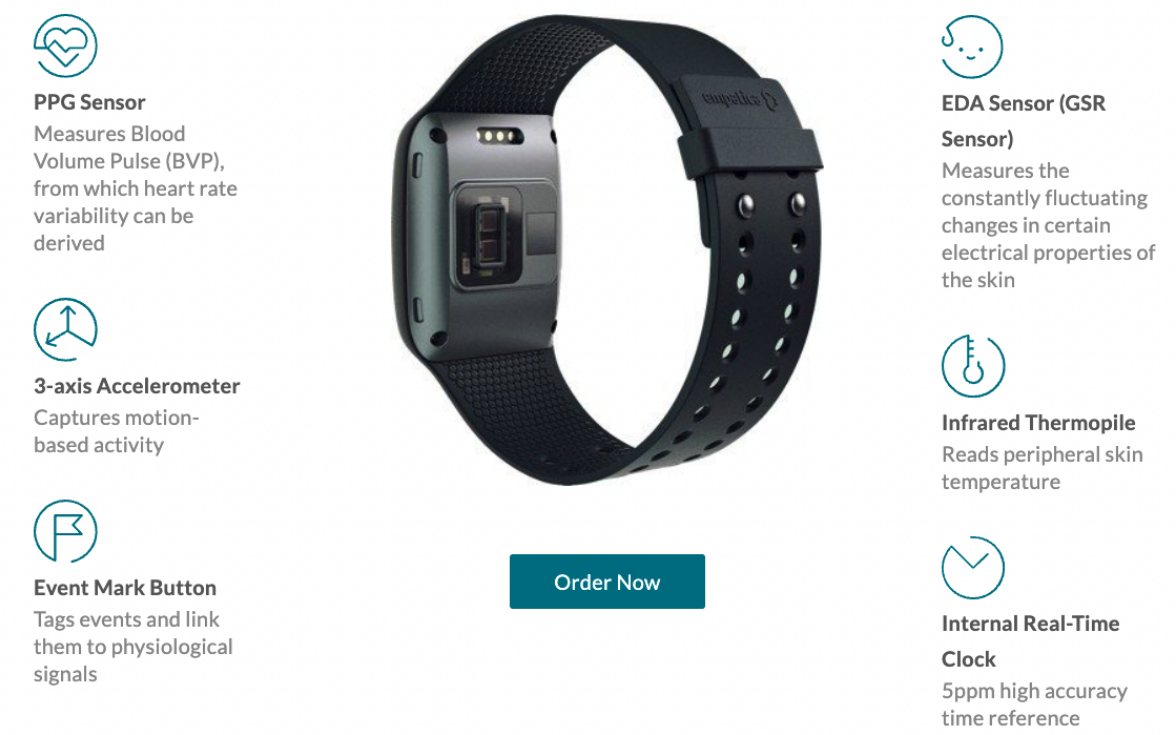

Figure 3-2: The Empatica E4 Wristband and Features, (Empatica Inc., 2020)

3-5-3 Mood Test

Friedman & Förster (2001, 2005) once developed a mood test, which consists of 6 negative affects and 6 positive affects items. They used it to check the extent to which a motivational arousal manipulation would be contaminated with emotional states students experienced. The example of negative items are 'worried', 'sad', and 'nervous'; and positive items are 'happy', 'relaxed', and 'joyful'. The scale was anchored at 1 (not at all) and 9 (extremely). As in (Friedman & Förster, 2001), this mood test was used to assess the validity of the motivational arousal intervention, and all items should be non-significant in theory.

Chapter 4

Results

4-1 Pilot Study

A week before the official experiment, a pilot study was completed. Five volunteers participated (2 women and 3 men). Through the pilot study, we identified what worked well and what did not work. Most importantly, the PANAS scale (incorporated in the beginning) was problematic. The volunteers considered it very vague and could not give reasonable answers. Therefore, this questionnaire was removed from the official experiment and was replaced by a mood testing developed by Friedman & Förster (2001, 2005).

4-2 Descriptive Statistics

In total, 66 volunteers participated in this experiment. Of these, 7 were removed because 6 volunteers did not complete the maze story correctly, while 2 volunteers did not describe anxiety-related campus experiences (one student was excluded twice). Thus, 59 data of participants (32 men and 27 women; M_{age} = 24.42 years, SD = 2.38) were used for analysis. The following Table 4-1 provides the demographic description of the sample. 61% participants come from Asia countries while 39% participants are Europeans (shown in Figure 4-1). Furthermore, 5 participants out of 59 were Behavioral Inhibition System (BIS)-driven.

Generalized Anxiety Disorder (GAD) As suggested by Spitzer et al. (2006), 10 is a cut-point for GAD distinction. In the present study, 20 participants scored equal to or greater than 10, meaning 33.9% of students suffer from GAD (Shown in Figure 4-2, Cronbach's α = .90, the internal consistency reliability of the scale is very good). The mean score of GAD-7 among GAD students was 14.70 (Std. = 3.29).

GAD Versus Motivational Arousal Manipulation In the present study, the motivational arousal variable had two values: approaching and avoidance arousal. Participants were classified into two groups based on the arousal condition they received. People who received the

Age	**Mean± Std.**
20∼31	24.42± 2.38
Gender	**Number**
Male	32
Female	27
Nationality	**Number**
Chinese	30
Dutch	12
Indian	3
Italian	3
Others	11
BIS/BAS Personality	**Number**
BIS	5
BAS	54
GAD	**Number**
GAD students	20
Non-GAD students	39

Table 4-1: Sample Demographic Feature

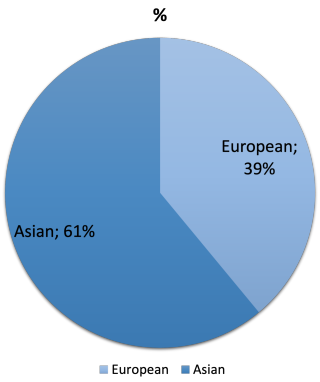

Figure 4-1: Nationality Distribution of Sample

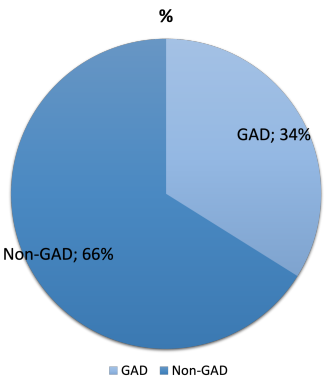

Figure 4-2: GAD and Non-GAD Students

approaching arousal setting were in the approaching group and the rest get the avoidance arousal manipulation and thus belonged to the avoidance group.

Table 4-2 displays the matrix of the number of motivational arousal manipulations and GAD. Nine GAD participants received approaching arousal manipulation while 11 GAD participants were in the avoidance group. In general, approaching and avoidance arousal manipulation were evenly distributed among students.

	Approaching Group	Avoidance Group	Total
GAD	9	11	20
Non-GAD	21	18	39
Total	30	29	59

Table 4-2: GAD Vs. Motivational Arousal Manipulation

Anxious-related Campus Experience Writing After administering the BIS/BAS, GAD-7 scales, and motivational arousal manipulation, participants were invited to write down anxious moments in their campus experience. This writing is seen to be a representative sample of language use and was analyzed by the Linguistic Inquiry and Word Count (LIWC) software. As a result, 2 subjects failed to describe experiences related to the anxiety, but instead described general experiences of college life or their own reflections. These 2 data were therefore excluded. As Table 4-3 displayed, the approaching group had 30 samples ($\text{Mean}_{wordcount} = 294$, Std. $= 127.86$), and the avoidance group had 29 samples ($\text{Mean}_{wordcount} = 361$, Std. $= 199.78$).

	Sample Size	Mean of Word Count	Std.
Approaching Group	30	294	127.86
Avoidance Group	29	361	199.78
Total	59	327	169.07

Table 4-3: Disclosure Writing Sample Summary

The LIWC internal dictionary has four general word categories, including more than 100 sub-categories (see Appendix A). LIWC analyzed users' mental states by recording the percentage of categorical words to total words. Since LIWC adopted a hierarchic category approach; the most commonly used word categories forming sentences are the most frequently used categories, i.e., personal pronouns, verbs, adverbs, and adjectives. The top 20 most frequently used LIWC categories in the sample are shown in Table 4-4. In first place was the Linguistic Dimensions, as the largest parent category, with an average of 75.83%. In fact, the majority of the top 20 were parent categories or sub-categories. These categories gave general information about the writing content, such as Past focus, Social processes, and Lifestyle, the three categories echoed the writing topic. The two groups showed no significant differences in these categories.

4-3 Arousal Manipulation Check: Mood Test

In the experiment, arousal manipulation was introduced by (Friedman & Förster, 2005). By definition, arousal manipulation is different from emotional manipulation. Therefore, this manipulation test examined whether the experiment triggered motivational arousal, rather than emotional arousal. For this purpose, a 12-item mood test was introduced. These 12 indicators were expected to be nonsignificant as the arousal manipulation adopted in this experiment was not a mood manipulation, and was set up subtly and cautiously, therefore, should not be perceived by the volunteers. Indeed, as shown in Table 4-5, all 12 items, 'worried', 'content', 'happy', 'relaxed', 'nervous', 'sad', 'disappointed', 'joyful', 'calm', 'tense',

No.	Categories	Abbrev.	Examples	Words in Category	Frequency of Sample* (%)
1	Linguistic Dimensions	Linguistic		4933	75.83
2	Totoal function words	function	the, to, and, I	1443	61.80
3	Common verbs	verb	is, was, be, have	1560	16.65
4	Determiners	det	the, at, that, my	293	16.51
5	Total pronouns	pronoun	I, you, that, it	286	16.35
6	Cognition	Cognition	is, was, but, are	1403	16.12
7	Cognitive processes	cogproc	but, not, if, or, know	1365	15.10
8	Prepositions	prep	to, of, in, for	302	13.44
9	Personal pronouns	ppron	I, you, my, me	221	11.42
10	1st person singular	i	I, me, my, myself	74	10.03
11	Auxiliary verbs	auxverb	is, was, be, have	282	8.78
12	Perception	Perception	in, out, up, there	1834	8.42
13	conjections	conj	and, but, so, as	65	7.92
14	Allure	allure	have, like, out, know	105	7.49
15	Common adjectives	adj	more, very, other, new	1507	7.46
16	Articles	article	a, an, the, alot	103	7.16
17	Adverbs	adverb	so, just, about, there	514	7.00
18	Past foucs	focuspast	was, had, were, been	699	6.79
19	Social processes	Social	you, we, he, she	2760	6.62
20	Lifestyle	Lifestyle	work, home, school, working	1437	6.30

1) Categories, Abbrev., Examples, and Words in Category were cited from (Boyd et al., 2022)
2) Frequency of Sample* was calculated by the mean of the sample
3) Full table see in Appendix A (LIWC-22 internal dictionary order)

Table 4-4: Top 20 Most Used Words Categories of the Sample

'depressed', and 'relieved', did not exhibit a significant value both in GAD and non-GAD group. This outcome suggested the success of the motivational arousal manipulation in the present study.

Mood Items	P-value		
	All	GAD	Non-GAD
Worried	0.20	0.88	0.83
Content	0.55	0.82	0.83
Happy	0.63	0.87	0.84
Relaxed	0.58	0.55	0.64
Nervous	0.52	0.77	0.99
Sad	0.73	0.56	0.89
Disappointed	0.97	0.50	0.84
Joyful	0.74	0.86	0.98
Calm	0.07	0.81	0.87
Tense	0.83	0.99	0.87
Depressed	0.83	0.96	0.86
Relieved	0.38	0.24	0.55

Table 4-5: Arousal Manipulation Check: Mood Test

4-4 Hypothesis Testing

This section is dedicated to answer the research question, finding and verifying correlations between variables.

4-4-1 Motivational Arousal Affects Language Categories Use

As mentioned in the first section, there is no difference between the two groups in terms of some general categories that reflect the writing topic or lexical properties (e.g., verbs, pronouns). This fact is straightforward and acceptable, as the limited sample size was inadequate to capture all differences effectively, and a number of words categories caused noise interference. Nevertheless, it is still promising to explore the correlation between language and motivational arousal. First, LIWC with correlation coefficient less than 0.113 with motivation arousal were removed (correlation coefficient $\rho_{median} = 0.113$). We considered these LIWC categories were interference groups, or, in other words, motivational arousal does not affect the performance of these language categories. As a result, 55 categories were reserved.

The Principal Components Analysis (PCA) is frequently applied to reduce the dimensions of a data set; thus, it was employed in the study to reduce the LIWC word categories. The 55 word categories were reduced to 15 while keeping 95% of the original data features (neglect arousal groups). Next, The k-means method helped to regroup the samples according to its statistical features, and the inter-group variability was optimized when group number was two (elbow point = 2). This outcome suggested that the language samples were best classified into two groups just according to its data distribution. Surprisingly, the precision/similarity between k-means and arousal groups was 68%, indicating the strong correlation between arousal levels and the general language text. The following Figure 4-3 displayed the k-means groups using the first three principal components (represent more than 60% of the language sample feature); while Figure 4-4 showed the language distribution of arousal groups. There is a remarkable fit between the two. Therefore, the first sub-question can be answered: the motivational arousal levels lead, to some extent, to the different language use of students.

In addition, the t-test was conducted to extract the language categories that were highly affected by motivated arousal. The result suggested that there were five LIWC categories significantly different across two groups ($p < 0.05$). They were: 'you', 'insight', 'cause', 'moral', 'fatigue'. Table 4-6 summarizes these five items, such as the means and standard deviations per category among two arousal groups and the psychological interpretations. The result is very interesting.

The approaching group used more 2nd person pronouns than the avoidance group. When examining the source data, it was found that participants in the approaching group used sentences to encourage themselves, such as 'Don't embarrass yourself', 'you can develop yourself'. In addition, they described their experiences more from the other person's perspective, e.g., 'everyone can hear the feedback that you get', 'if you pass the score, you will be fine'. At the same time, the approaching group was more rational in describing their experiences. They dug into the context of what happened, insights, and subjective judgment. Conversely, the avoidance group used more fatigue-related words. This was in line with the avoidance motivational arousal, where people were more fatigued when dealing with punishment arousal than reward arousal.

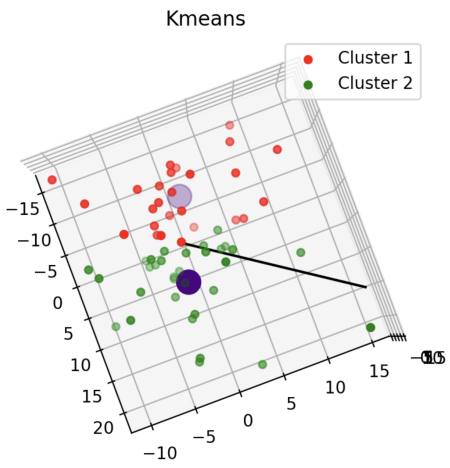

Figure 4-3: K-means Groups Based on Statistics of LIWC Categories

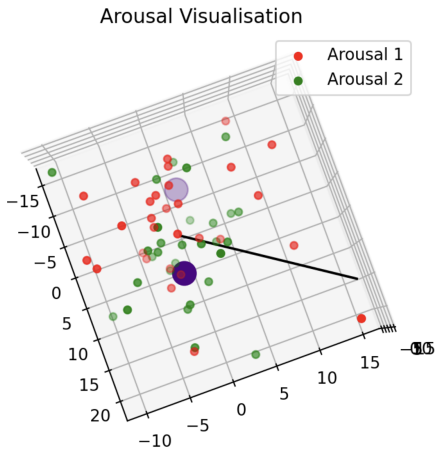

Figure 4-4: Arousal Groups Divided by Different Arousal Levels

4-4-2 GAD moderates Language Use

The direction of GAD moderated language use was negative. As displayed in Table 4-7, the 59 samples were divided into a GAD group and a non-GAD group. In the GAD group, the similarity/precision between the arousal groups and the k-means groups was decreased to 55% (total sample precision was 68%), implying that GAD prevented/diminished the strength of motivational arousal. The probability of a random point falling into the approaching/avoidance group is equal to 0.5. In such a situation, the statistic grouping is irrelevant to arousal grouping. This fact suggests that GAD prevents the activation of arousal. In contrast, in the non-GAD group, the similarity between the k-means and arousal groups increased to 74.36%, meaning that non-anxious students were more sensitive to motivational arousal. The finding echos with the prior studies on sympathetic activation in GAD (seen in subsection 2-4-2): people with GAD were posited to have 'diminished physiological flexibility' with a smaller physiological response to stressors compared to non-anxious people (Hoehn-Saric et al., 1989). In contrast, non-anxious people showed a faster response under stress. Motivational arousal can be seen as a stressor, GAD students appear a diminished response to stressors both in bodily and in language use. Therefore, the second sub-question was answered that the GAD influences students' language use by inhibiting the arousal effect.

The following Table 4-8 demonstrated the impact of GAD within each of the two arousal groups. Overall, there was no significant difference in language use between GAD and non-GAD students within each arousal group. Nevertheless, non-anxious students used more 2nd person pronouns than anxious students, and the anxious student group was inclined to provide more insights when writing their personal experiences.

Categories**	Abbrev	Examples	Words*	Psychological Interpretations	Approaching Group Mean (%)	Approaching Group Std.	Avoidance Group Mean (%)	Avoidance Group Std.	P-value
2nd person	you	you, your, yourself	59	people who are more confident and higher in social standings tend to use "you" words at relatively high rates	0.52	1.00	0.13	0.29	0.049
Insight	insight	know, how, think, feel	383	-	4.17	1.80	3.28	1.47	0.042
Causation	cause	how, because, why	169	belongs to cognitive process category	2.28	1.17	1.67	1.00	0.034
Moralization	moral	wrong, honor, judge	356	Moralization or words reflecting judgemental language, often where the speaker makes a moral evaluation (either good or bad) about another's behavior or character (Brady et al., 2020)	0.22	0.36	0.04	0.10	0.014
Fatigue	fatigue	tired, bored, don't care	66	Fatigue words often reflect exhaustion, boredom, or expended effort (Hockey & Hockey, 2013)	0.03	0.13	0.18	0.33	0.028

Words* = Words in Category
Categories**, Examples, Words*, and Psychological Interpretations were cited from (Boyd et al., 2022)

Table 4-6: Significantly Different LIWC Word Categories Use between Two Arousal Groups

	Sample Size	Precision	Interpretation
GAD	20	55%	GAD moderates language use by inhabiting arousal effect
Non-GAD	39	74.36%	Non-anxious students were more sensitive to arousal manipulation
All	59	68%	Motivational arousal leads to different use of language

Table 4-7: The Precision between K-means and Arousal Groups

4-5 Exploration of Sympathetic Activation Process

This section will explore the sympathetic activation activities, triggered by motivational arousal and affected by GAD. In addition, answer the 3rd and 4th sub-questions.

4-5-1 Physiological Data Processing and Statistics

In the present experiment, participants were instructed to wear an Empatica wristband on their non-dominant hands throughout the experiment. Prior to the official start (distribute booklet), the wristband has recorded at least 10-minute of the participants' baseline physiological levels (i.e., Heart Rate (HR), Electrodermal Activity (EDA) and temperature). As the workshop progressed, students were asked to record the experiment phase by pressing the 'event' button on the wristband. As illustrated in Figure 4-5, in total six 'events' (6 tags) were recorded: The formal beginning and ending of the experiment, the start and end of the

Categories	Abbrev.	Examples	Approaching Group							Avoidance Group						
			All		GAD		Non-GAD		P-value	All		GAD		Non-GAD		P-value
			Mean (%)	Std.	Mean (%)	Std.	Mean (%)	Std.		Mean (%)	Std.	Mean (%)	Std.	Mean (%)	Std.	
2nd person	you	you, your, yourself	0.52	1.00	0.49	1.17	0.54	0.94	0.912	0.13	0.29	0.12	0.28	0.14	0.31	0.803
Insight	insight	know, how, think, feel	4.17	1.80	4.25	2.08	4.13	1.72	0.882	3.28	1.47	3.44	1.63	3.18	1.40	0.672
Causation	cause	how, because, why	2.28	1.17	2.60	1.55	2.15	0.98	0.437	1.67	1.00	1.21	1.06	1.95	0.88	0.068
Moralization	moral	wrong, honor, judge	0.22	0.36	0.28	0.38	0.19	0.36	0.521	0.04	0.10	0.00	0.00	0.06	0.12	0.047
Fatigue	fatigue	tired, bored, don't, care	0.03	0.13	0.00	0	0.05	0.16	0.176	0.18	0.33	0.15	0.23	0.20	0.38	0.660

Table 4-8: The GAD Effect on the Language of Each Arousal Group

motivational arousal manipulation, and the onset and the end of personal experience writing. These six moments divided the experimental process into six phases, namely baseline, BIS/Behavioral Approach System (BAS) and GAD-7 scales, motivational arousal manipulation, mood test, anxious campus experience writing, and general information recording (i.e., gender, age, and nationality) with arousal manipulation check (i.e., multiple questions on manipulation type and story title).

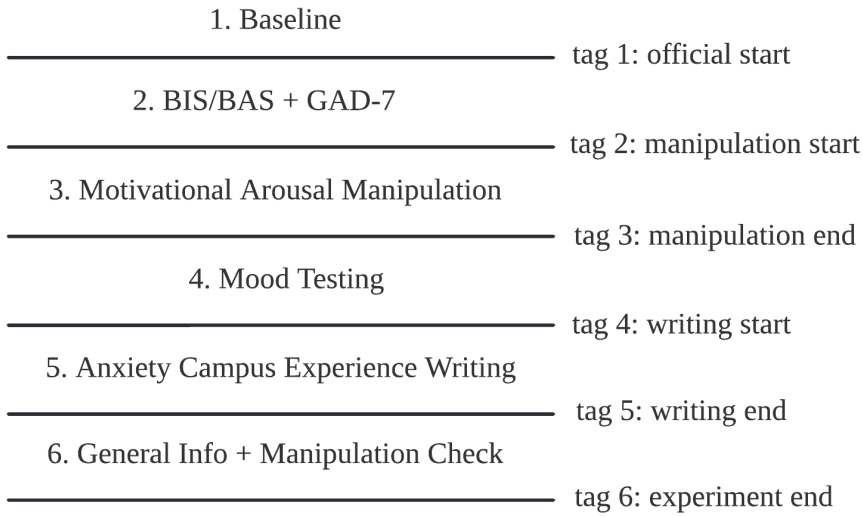

Figure 4-5: Experiment Phases and Tags

Data Cleaning To ensure that volunteers can properly record the experiment phases by pressing the button on the wristband. Volunteers were instructed to try pressing the button during the baseline segment. Immediately after the experiment, the tags were checked via Empatica Connect, and the data was recorded manually, i.e., how many attempts were made

and whether there were any missing tags in the middle course. If the volunteer forgets to press the button once or several times, the volunteer is required to recall and estimate the approximate duration. Accordingly, the tag data collected from the wristbands were manually cleaned and ultimately exact six valid tags were retained per sample.

Experiment Phases Duration The average duration of the experiment was 55 minutes (see Table 4-9), and the avoidance group spent longer time than the approaching group, mainly in the arousal manipulation and self-disclosure writing phases.

	Min.	**Mean**	**Max.**	**Mean**	
				Approaching Group	Avoidance Group
Baseline	10	12	15	12	12
Anxiety scales	2	8	15	9	8
Arousal manipulation	6	17	32	15	17
Mood check	0.5	2	10	2	2
Discloser Writing	3	14	33	14	16
General info	0.6	2	4	2	2

Table 4-9: Experiment Time Summary (in minutes)

Descriptive Table of Physiological Data After cleaning the data, for each participant, means and standard deviations were calculated for each parameter at three each phase. In total, there were six phases, and three out of them were questionnaires, which took little time and thus were neglected in this part. The Empatica wristband provided all data except Heart Rate Variability (HRV), which was calculated using an open-sourced package provided by (Caviola & Faber, 2014). The mean reflects the average level at each phase and the standard deviation captures the fluctuations at that phase. Later, the means of the two data were obtained according to the motivational arousal level, as displayed in Table 4-10.

4-5-2 Motivational Arousal Manipulation Triggers Sympathetic Activation

In order to answer the effect of motivational arousal in terms of physiological performance, physiological data at baseline level and during motivational arousal manipulation will be used. These two phases were extracted and analysed in this part. The data collected 10 minutes before the official start of the experiment was referred to as the baseline. Generally, an individual's baseline level can be used as the basis for comparison. For each participants, the mean and standard deviation of the physiological parameters at both stages were calculated separately, representing the general level and the fluctuation at both stages. Next, t-tests of involved parameters (mean and mean of standard deviation) between both phases were implemented. As a result, the mean of the standard deviation of HR and HRV was significantly different, suggesting that the arousal manipulation affected the fluctuation level of the HR and HRV. More specifically, such manipulation reduced the HR and HRV variation (see Table 4-10).

Subsequently, the data of each parameter was further aggregated and examined at the arousal manipulation level. Interestingly, motivational arousal (either approaching or avoidance)

Parameter	Group	Phases					
		Baseline		Arousal Manipulation		Self Disclosure Writing	
		Mean	Std.*	Mean	Std.*	Mean	Std.*
HR [bps]	All	77.29	4.78	77.28	3.06	76.48	3.29
	Approaching	76.19	4.69	75.85	2.59	75.26	3.11
	Avoidance	78.42	4.87	78.76	3.54	77.75	3.46
HRV [ms]	All	803.80	64.68	797.27	55.35	802.55	56.54
	Approaching	809.12	64.68	798.76	54.62	807.38	55.81
	Avoidance	798.30	64.69	795.72	56.10	797.55	57.30
EDA [μS]	All	1.66	0.48	1.49	0.35	1.45	0.22
	Approaching	1.42	0.41	1.35	0.27	1.59	0.20
	Avoidance	1.90	0.55	1.64	0.44	1.32	0.24
Temp [$^{\circ}C$]	All	31.70	0.33	32.37	0.19	32.48	0.14
	Approaching	31.42	0.33	32.07	0.17	32.13	0.12
	Avoidance	32.00	0.33	32.70	0.20	32.84	0.17

1) Std.* is the mean of sample Std.

Table 4-10: Descriptive Values of Physiological Data

caused a decrease in skin conductivity (EDA) and in HRV of both groups. A decrease in HR of the approaching group but an increase in the avoidance group. At the same time, such arousal manipulation has made the fluctuations of the physical indicators smaller (see Table 4-11 and Figure 4-6). This phenomenon can be explained: when participants were under arousal manipulation unconsciously, especially for those in the avoidance group, the HR response was strengthened (Jouven et al., 2009); while for those in the approaching group, as the manipulation was pleasant, thus, the HR was slightly decreased (Fairhurst et al., 2014; Pollatos et al., 2007). And the arousal maintained such response at a certain level, therefore, the fluctuation become smaller (the mean of Std. p-value < 0.05 for HR). The changes in skin conductance activity confirmed the sympathetic activation. At this point, the third sub-question of this study can be answered: the motivational arousal led to sympathetic activation, both in approaching and avoidance manipulation.

		Mean			**Mean of Std.**		
		Baseline	Arousal	P-value	Baseline	Arousal	P-value
HR [bps]	Approaching	76.19	75.85	0.89	4.69	2.59	**8.09e-04**
	Avoidance	78.42	78.76	0.92	4.87	3.54	0.06
HRV [ms]	Approaching	809.12	798.76	0.72	64.68	54.62	**0.02**
	Avoidance	798.30	795.72	0.95	64.69	56.10	0.19
EDA [μS]	Approaching	1.42	1.35	0.90	0.41	0.27	0.29
	Avoidance	1.90	1.64	0.66	0.55	0.44	0.56
Temp [$^{\circ}C$]	Approaching	31.42	32.07	0.10	0.33	0.17	**6.18e-04**
	Avoidance	32.00	32.70	0.09	0.33	0.20	**0.04**

Table 4-11: Arousal Manipulation Effect

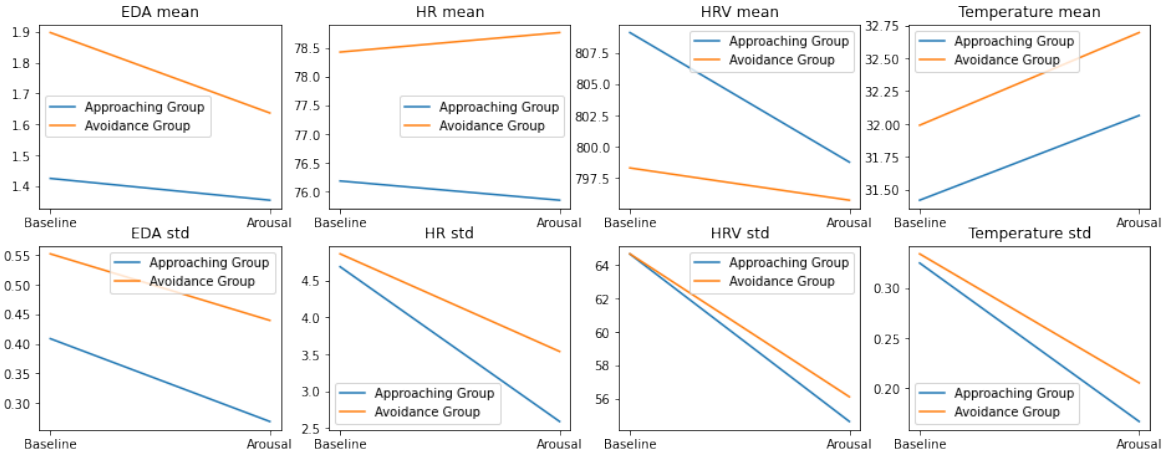

Figure 4-6: Mean and Mean of Std. between Baseline and Arousal Manipulation Phase

4-5-3 GAD Regulates Sympathetic Activation

Lastly, the study explored the effect of GAD on sympathetic activation. Given the small sample size, the direction of sympathetic activation of motivational arousal was mostly consistent. The distinction between levels of motivational arousal was not made here. As Figure 4-7 illustrated, GAD students presented a 'diminished physiological flexibility' (Hoehn-Saric et al., 1989) in all four physiological dimensions. With the arousal manipulation, the differences in the average level of EDA, HRV, and the skin temperature of GAD students at two phases were smaller than that of non-GAD students. This outcome was in line with the previous studies on sympathetic activation in GAD (seen in subsection 2-4-2) and also in line with the finding that the GAD inhabits the language use 'flexibility' (stated in subsection 4-4-2). Nevertheless, the fluctuation was almost the same between GAD and non-GAD groups. In addition, the reduced EDA (Hoehn-Saric et al., 1989), and increased HR (Thayer et al., 1996) among GAD people under stress were again, confirmed in the present study. In the end, it seems that the 4th sub-question has been answered: GAD students differ in terms of sympathetic activation from participants with a low score on GAD.

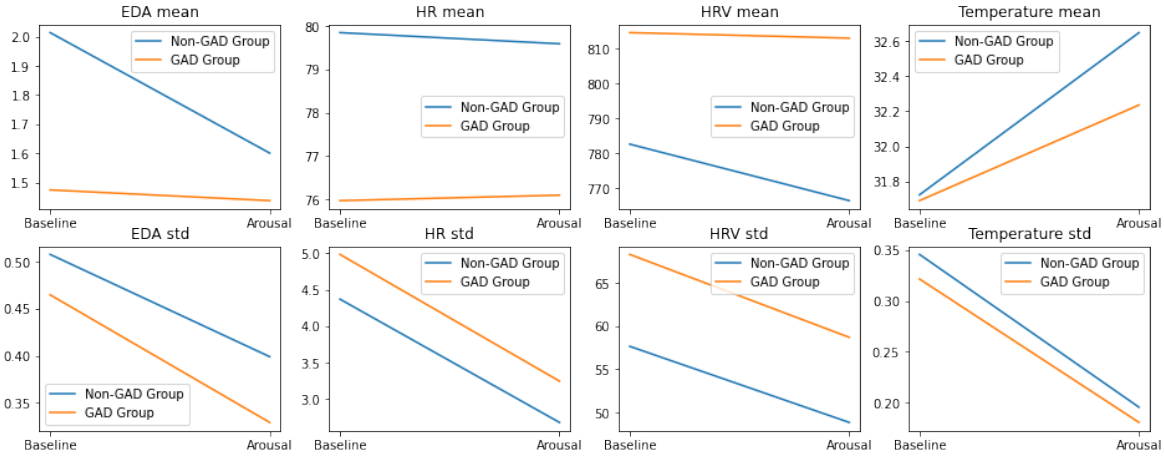

Figure 4-7: Mean and Mean of Std. between GAD and Non-GAD Group

Chapter 5

General Discussion

A Randomized Controlled Trial (RCT) was conducted, in which motivational arousal was the independent variable, the natural language was the dependent variable, Generalized Anxiety Disorder (GAD) was the moderate variable, and sympathetic activation was the mediate variable. It was found that motivational arousal led to differences in students' language use, and at the same time, motivational arousal triggered sympathetic activation. Last but not least, the motivational arousal was affected by the level of students' GAD scores. All findings in the present study are interesting and insightful. This chapter will be dedicated to discussing these findings in terms of the scientific and practical relevance, as well as the study limitations and future work.

5-1 Scientific Relevance

The present study made a great contribution in terms of scientific relevance.

Motivational Arousal Affects Language Use Most research on motivational arousal and language has focused on pronouns and positive and negative emotional words. For example, negative words such as *coffin* tended to evoke slower lexical decisions (Wentura et al., 2000), and slower word naming (Algom et al., 2004) than neutral words such as *cotton*. Exciting words were recognized faster than other words. Other than that, it has been shown that understanding action words (as an external stimulus) affects arousal level and activates approach and avoidance motor processes (Claus & Bader, 2008). However, in the present study, these results were not significantly represented. This may be attributed to the writing topic: participants were asked to describe anxious (negative) experiences in their university life. Regardless of the arousal group, volunteers had to use first-person pronouns and some negative emotional words. For example, first-person singular pronouns were used at a rate of 10%. Instead, we found that students in the avoidance group used more words from the 'fatigue' category. People always seem tired when dealing with troubles. Meanwhile, the approaching group used more second-person pronouns ('you', 'yourself') than the Avoidance group to

encourage themselves or to put themselves in the other person's ('you') shoes thinking and giving more insights and judgments. In addition, approach leads to insight was first found by (Friedman & Förster, 2001, 2002, 2005), it was confirmed this with a linguistic outcome measure that the approaching group using more insight and judgment words.

GAD moderates Language Use Previous studies have already established that human language use is a reflection of the inner world. When GAD was of interest, people with GAD were found to use more first-person singular pronouns and negative emotion words (Lyons et al., 2018). (Rook et al., 2022)'s study suggests that negatively valenced emotion words and words related to social processes may be sufficient to identify GAD. These studies demonstrate the strong correlation between GAD and language. In this study, this relationship was once again confirmed; in addition, the direction of GAD moderated language use was negative under motivational arousal. In other words, GAD prevents the activation of arousal. Motivational arousal is particularly challenging for people with GAD. This finding is in line with the previous study in autonomic nervous activities and affects that patients with GAD were posited to have 'diminished physiological flexibility' with a smaller physiological response to stressors compared to non-anxious people (Hoehn-Saric et al., 1989). In the present study, the psychological dimension also showed a similar pattern.

Motivational Arousal Manipulation Triggers Sympathetic Activation We have learned that Heart Rate Variability (HRV) and Electrodermal Activity (EDA) are the two most prominent indicators of sympathetic activation (Roth et al., 2008). In addition, it is noted from laboratory studies that physiological signals such as EDA and heart rate can map psychological distress (Nock & Mendes, 2008; Lazarus et al., 1962). Therefore, EDA, Heart Rate (HR), and HRV were were highlighted for study. We learned that the motivational arousal (either approaching or avoidance) caused a decrease in skin conductivity (EDA) and in HRV of both groups. This seems unreasonable, because normally EDA tends to increase (Bartolomé-Tomás et al., 2020). However, this is not the case in the present study. Under affective arousal, EDA increases with sweat secretion. The current experiment was arousal manipulation, and emotions were not aroused and were checked in mood testing. Other than that, it is interesting that a decrease in HR of the approaching group but an increase in the avoidance group. At the same time, such arousal manipulation has made the fluctuations of the physical indicators smaller. This result was consistent with the previous studies (see subsection 4-5-2).

GAD Regulates Sympathetic Activation As mentioned earlier, the GAD group has 'diminished physiological flexibility' with a smaller physiological response to stressors compared to non-anxious people (Hoehn-Saric et al., 1989; Lader & Wing, 1964). That is, people with GAD show smaller variability in terms of physiological indicators. Consistent results were observed in this experiment regarding the inflexibility in EDA, HR, and HRV. Furthermore, the reduced EDA (Hoehn-Saric et al., 1989), and increased HR (Thayer et al., 1996) among GAD people under stress were again, confirmed in the present study. Lastly, we found out that the fluctuation of each indicator was almost the same between GAD and non-GAD groups, which was unexpected. Instead, it was assumed that the non-GAD group's fluctuation would

be larger because non-anxious people were more sensitive to the stress (Hoehn-Saric et al., 1989).

5-2 Practical Relevance

Mobile technology has changed the way people communicate. Text-based and voice-message-driven fragmented chat applications have been widely accepted (Dale, 2016; Greenberg, 2018). At the same time, online conversational chatbots are attracting ever more attention for their enormous economic and social welfare potential. Interactive conversational chatbots, as a fruit of machine learning, have the potential to communicate one-on-one with users and respond quickly and accurately to their needs (Mislevics et al., 2018). More recently, Internet Cognitive Behavioral Therapy (iCBT) in the treatment of GAD has been developed and proven its efficiency both in research findings and primary care settings (Christensen et al., 2009; Titov et al., 2009; Andrews et al., 2010; Griffiths et al., 2010; Robinson et al., 2010; Mewton et al., 2012; Carl et al., 2020; Trenoska Basile et al., 2022).

This study explored the associations between language and anxiety, motivational stimuli, and signals of the body. The conclusions obtained can be either applied to eHealth applications or to the development of chatbots to identify anxiety disorders. Taking chatbots as an example, a chatbot that imitates a psychotherapist can be developed. Check users' language usage habits to reasonably suspect GAD, such as on-anxious people would use more 2nd person pronouns than anxious people, and the anxious group is inclined to provide more insights when writing their personal experiences. Together with the previous study's findings, it is promising that such a chatbot is up to the challenge and capable of providing follow-up services. Furthermore, if the wristband can be designed (like the Empatica E4 wristband) to capture the physical data. The eHealth system would be more reliable, e.g., less fluctuation of physiological data in GAD patients when under arousal manipulation.

5-3 Limitations

The study yielded good results, but several limitations deserve attention.

BIS/BAS Proportion of Sample Among 59 participants, 54 participants were characterized by Behavioral Approach System (BAS)-driven. First, there is a strong correlation between anxiety (tendency) and Behavioral Inhibition System (BIS). Most of the samples were BAS system driven, which may have led to sample error. Second, the degree of motivational arousal is related to individual differences, with people in the BAS system being more sensitive to approaching arousal than avoidance arousal. This may also be a limitation of the present study.

Failed to Valid Some Words Categories Most studies (Rook et al., 2022; Wentura et al., 2000; Algom et al., 2004; Estes & Adelman, 2008) in psychology and language have focused on word categories like first-person pronouns, positive emotions, and negative emotions, as reviewed in section 2-3. The present study did not exhibit a significant result from the

prior studies. There might be several reasons: firstly, the study objects were different; for example, prior studies have examined personality traits, while this study is grounded in arousal manipulation. Secondly, participants were asked to write a fixed-topic experience and express their feelings and emotions, i.e., anxious campus experience, which inevitably guided participants to use more anxious, negative emotion-related vocabulary; therefore, it was ineffective in comparing the usage of the emotional word. Lastly, the sample size was limited, which may cause sample bias.

Small Sample Size The sample size of the present study was 59, which seems satisfactory. However, because of two layers of variables, motivational arousal and GAD, it seems limited. For example, when I wanted to study the effect of GAD under approaching motivational arousal, only nine samples belonged to this group. With nine samples, it is still possible to observe the pattern. But it is very limited to get statistical significance, which harms the reliability of the study.

5-4 Future Work

This study can be extended in many ways. For example:

EEG One of the main physical symptoms of GAD is muscle tension. And Electroencephalogram (EEG) is an important signal to capture this symptom. EEG records specific brain activities. Changes in brain activity associated with anxiety disorders include EEG markers of error-related negativity (ERN) and correct response negativity (CRN), both of which are thought to reflect the pathophysiology of response monitoring and attentional control in anxiety disorders (Michael et al., 2021). Future studies could introduce EEG with another equipment or would more accurately differentiate between patients with anxiety disorders.

HRV In addition, HRV showed good significance in arousal manipulation in the present study. However, it is not yet properly validated. Maybe focusing on the HRV signal in the future study is a good choice; because the HRV is seen as a measure of the variability in our autonomic nervous system. That is, the HR reflects adaptability to external triggers (Petrowski et al., 2017). Furthermore, the HRV has been said to be chronically low in the resting state of anxious patients (Held et al., 2021; Chung et al., 2021). Thus, to study HRV in more detail under the motivational arousal setting is meaningful and is a great way to connect anxiety and language altogether. Furthermore, EEG might facilitate the alignment with HRV.

Skin Temperature Also, we observed that the skin temperature was greatly influenced by motivational arousal. However, the present study failed to interpret this pattern. Future studies could pay attention to this signal and give a more comprehensive and convincing explanation.

The Sympathetic Activation and Expressive Writing The present study also collected physiological data during expressive writing. However, it has not been studied. It is interesting to look at the sympathetic activation during writing or to compare the physiological patterns during baseline, motivational arousal manipulation, and expressive writing. It has been validated that disclosure writing is a good way of mental disorder treatment. Maybe it will show some pattern in the physiological dimension.

Verbal Language The present study adopted free text, it may be a direction to look at the verbal language. the conversation is a primary way in Cognitive Behavioral Therapy (CBT), and people may have different language patterns in writing and speaking. This direction could extend the present study, making it more thorough. The results generated could be better employed in, e.g., conversational chatbot development, providing more practical as well as scientific relevance.

5-5 Conclusion

The initial subject of the study was motivational arousal, language, and GAD. After the literature review, sympathetic activation attracted interest because it connects mental and physical states together, making the study more comprehensive. Therefore, I aimed to understand more relevance of these four concepts. For realizing this objective, the hypotheses were developed based on the previous study, and four research sub-questions were proposed. Then a RCT was designed, in which motivational arousal was represented by a mouse maze story writing (Friedman & Förster, 2001, 2005) and the sample size in both arousal groups was the same. The GAD was detected by the GAD-7 scale, with a total score of 10 (including 10) being a cut-point that divided the samples into an anxious group and a non-anxious group. The language sample was free-text: the students were allowed to write about their anxious campus experience. Such a method originated from Pennebaker's (1997) study and was widely adopted in academia. Later, the language sample was digested by Linguistic Inquiry and Word Count (LIWC) application which generated the usage frequency of word categories. For sympathetic activation, the Empatica E4 wristband was help to capture the physiological data, more specifically, we focused on HR and EDA. The two were said to be indicators of sympathetic activation.

The findings were inspirational as they not only answered the research question successfully but also generated some unexpected results. Firstly, motivational arousal leads to different language use of students. Especially, 'fatigue', 'you', 'insight', and 'Moralization' word categories showed significant differences between the two arousal groups. Next, GAD influences the language use of students, given certain motivational arousal. We found out that non-GAD students could use more second-person pronouns. In addition, the GAD inhibited the effect of the motivational arousal, which refers to a diminished response to the motivational arousal in terms of language use. Thirdly, Motivational arousal manipulation obviously triggers sympathetic activation in participants. HR and HRV variability of participants decreased by arousal manipulation. The EDA was reduced during the manipulation was an unexpected result. Lastly, GAD students, again, presented inhibition of motivational arousal on sympathetic activation, which echos the second finding and validates the previous studies once again. In this regard, the main research question can be answered: the motivational arousal

and GAD influence the language use of students. In addition to answering the research questions, it is delightful that the results of the present study were highly consistent with previous studies.

The present study has successfully linked external stimuli, psychophysiological states, and linguistic expression in an organic way. The results obtained have great scientific and practical relevance, provide guidance for future work, and offer a wealth of directions for an extension.

Appendix A

LIWC-22 Language Frequency of the Sample

Table A-1: LIWC Category Frequency of the Sample

Categories	Abbrev.	Examples	Words	Frequency (%)
Linguistic Dimensions	Linguistic		4933	73.82
Total function words	function	the, to, and, I	1443	59.83
Total pronouns	pronoun	I, you, that, it	74/286	15.40
Personal pronouns	ppron	I, you, my, me	42/221	10.49
1st person singular	i	I, me, my, myself	6/74	9.30
1st person plural	we	we, our, us, lets	7/17	0.27
2nd person	you	you, your, u, yourself	14/59	0.33
3rd person singular	shehe	he, she, her, his	30	0.15
3rd person plural	they	they, their, them, themsel*	7/20	0.32
Impersonal pronouns	ipron	that, it, this, what	32/68	4.92
Determiners	det	the, at, that, my	97/293	15.8
Articles	article	a, an, the, alot	3/103	6.77
Numbers	number	one, two, first, once	44/61	1.48
Prepositions	prep	to, of, in, for	83/302	13.39
Auxiliary verbs	auxverb	is, was, be, have	25/282	8.59
Adverbs	adverb	so, just, about, there	159/514	6.50
Conjunctions	conj	and, but, so, as	49/65	7.89
Negations	negate	not, no, never, nothing	8/247	1.74
Common verbs	verb	is, was, be, have	1560	16.11
Common adjectives	adj	more, very, other, new	1507	7.78
Quantities	quantity	all, one, more, some	422	5.48

Categories	Abbrev.	Examples	Words	Frequency (%)
Psychological Processes				
Drives	Drives	we, our, work, us	1477	4.42
Affiliation	affiliation	we, our, us, help	384	1.23
Achievement	achieve	work, better, best, working	277	2.25
Power	power	own, order, allow, power	856	1.09
Cognition	Cognition	is, was, but, are	1403	15.43
All-or-none	allnone	all, no, never, always	35	1.01
Cognitive processes	cogproc	but, not, if, or, know	1365	14.35
Insight	insight	know, how, think, feel	383	3.67
Causation	cause	how, because, make, why	169	1.94di
Discrepancy	discrep	would, can, want, could	108	1.75
Tentative	tentat	if, or, any, something	230	1.85
Certitude	certitude	really, actually, of course, real	131	0.92
Differentiation	differ	but, not, if, or	325	4.32
Memory	memory	remember, forget, remind, forgot	26	0.13
Affect	Affect	good, well, new, love	2999	6.36
Positive tone	tone_pos	good, well, new, love	1020	3.42
Negative tone	tone_neg	bad, wrong, too much, hate	1530	2.84
Emotion	emotion	good, love, happy, hope	1030	3.33
Positive emotion	emo_pos	good, love, happy, hope	337	1.12
Negative emotion	emo_neg	bad, hate, hurt, tired	618	2.08
Anxiety	emo_anx	worry, fear, afraid, nervous	120	1.49
Anger	emo_anger	hate, mad, angry, frustr*	181	0.14
Sadness	emo_sad	:(, sad, disappoint*, cry	134	0.15
Swear words	swear	shit, fuckin*, fuck, damn	462	0.00
Social behavior	socbehav	said, love, say, care	1632	2.51
Prosocial behavior	prosocial	care, help, thank, please	242	0.40
Politeness	polite	thank, please, thanks, good morning	142	0.04
Interpersonal conflict	conflict	fight, kill, killed, attack	305	0.14

Categories	Abbrev.	Examples	Words	Frequency (%)
Moralization	moral	wrong, honor*, deserv*, judge	356	0.12
Communication	comm	said, say, tell, thank*	350	0.96
Social referents	socrefs	you, we, he, she	1232	2.93
Family	family	parent*, mother*, father*, baby	194	0.05
Friends	friend	friend*, boyfriend*, girlfriend*, dude	102	0.43
Female references	female	she, her, girl, woman	254	0.87
Male references	male	he, his, him, man	230	0.22
Expanded Dictionary				
Culture	Culture	car, united states, govern*, phone	772	0.40
Politics	politic	united states, govern*, congress*, senat*	339	0.07
Ethnicity	ethnicity	american, french, chinese, indian	239	0.08
Technology	tech	car, phone, comput*, email*	202	0.29
Lifestyle	Lifestyle	work, home, school, working	1437	6.20
Leisure	leisure	game*, fun, play, party*	295	0.37
Home	home	home, house, room, bed	122	0.19
Work	work	work, school, working, class	547	5.46
Money	money	business*, pay*, price*, market*	281	0.19
Religion	relig	god, hell, christmas*, church	241	0.05
Physical	Physical	medic*, food*, patients, eye*	1993	0.86
Health	health	medic*, patients, physician*, health	715	0.36
Illness	illness	hospital*, cancer*, sick, pain	259	0.18
Wellness	wellness	healthy, gym*, supported, diet	118	0.06
Mental health	mental	mental health, depressed, suicid*, trauma*	126	0.07
Substances	substances	beer*, wine, drunk, cigar*	154	0.00

Categories	Abbrev.	Examples	Words	Frequency (%)
Sexual	sexual	sex, gay, pregnan*, dick	357	0.00
Food	food	food*, drink*, eat, dinner*	379	0.09
Death	death	death*, dead, die, kill	109	0.03
States				
Need	need	have to, need, had to, must	55	0.54
Want	want	want, hope, wanted, wish	56	0.35
Acquire	acquire	get, got, take, getting	74	0.73
Lack	lack	don't have, didn't have, *less, hungry	89	0.15
Fulfilled	fulfill	enough, full, complete, extra	49	0.35
Fatigue	fatigue	tired, bored, don't care, boring	66	0.11
Motives				
Reward	reward	opportun*, win, gain*, benefit*	62	0.21
Risk	risk	secur*, protect*, pain, risk*	128	0.31
Curiosity	curiosity	scien*, look* for, research*, wonder	76	0.46
Allure	allure	have, like, out, know	105	7.48
Perception	Perception	in, out, up, there	1834	7.63
Attention	attention	look, look* for, watch, check	130	0.29
Motion	motion	go, come, went, came	485	1.25
Space	space	in, out, up, there	617	5.09
Visual	visual	see, look, eye*, saw	226	0.30
Auditory	auditory	sound*, heard, hear, music	255	0.06
Feeling	feeling	feel, hard, cool, felt	157	0.99
Time orientation				
Time	time	when, now, then, day	464	5.60
Past focus	focuspast	was, had, were, been	699	6.39
Present focus	focuspresent	is, are, I'm, can	373	3.76
Future focus	focusfuture	will, going to, have to, may	138	1.03
Conversational	Conversation	yeah, oh, yes, okay	500	0.07
Netspeak	netspeak	:), u, lol, haha*	439	0.04
Assent	assent	yeah, yes, okay, ok	50	0.04

Categories	Abbrev.	Examples	Words	Frequency (%)
Nonfluencies	nonflu	oh, um, uh, i i	21	0.00
Fillers	filler	rr*, wow, sooo*, youknow	24	0.00

1) Categories, Abbrev., Examples, and Words in Category were cited from (Boyd et al., 2022)
2) Frequency of Sample* were calculated by the mean of the sample

Appendix B

Physiological Data Comparison

The Physiological parameters comparison (mean, and the mean of the Std.) across different experimental stages were displayed in the following Figure B-1 and Figure B-2.

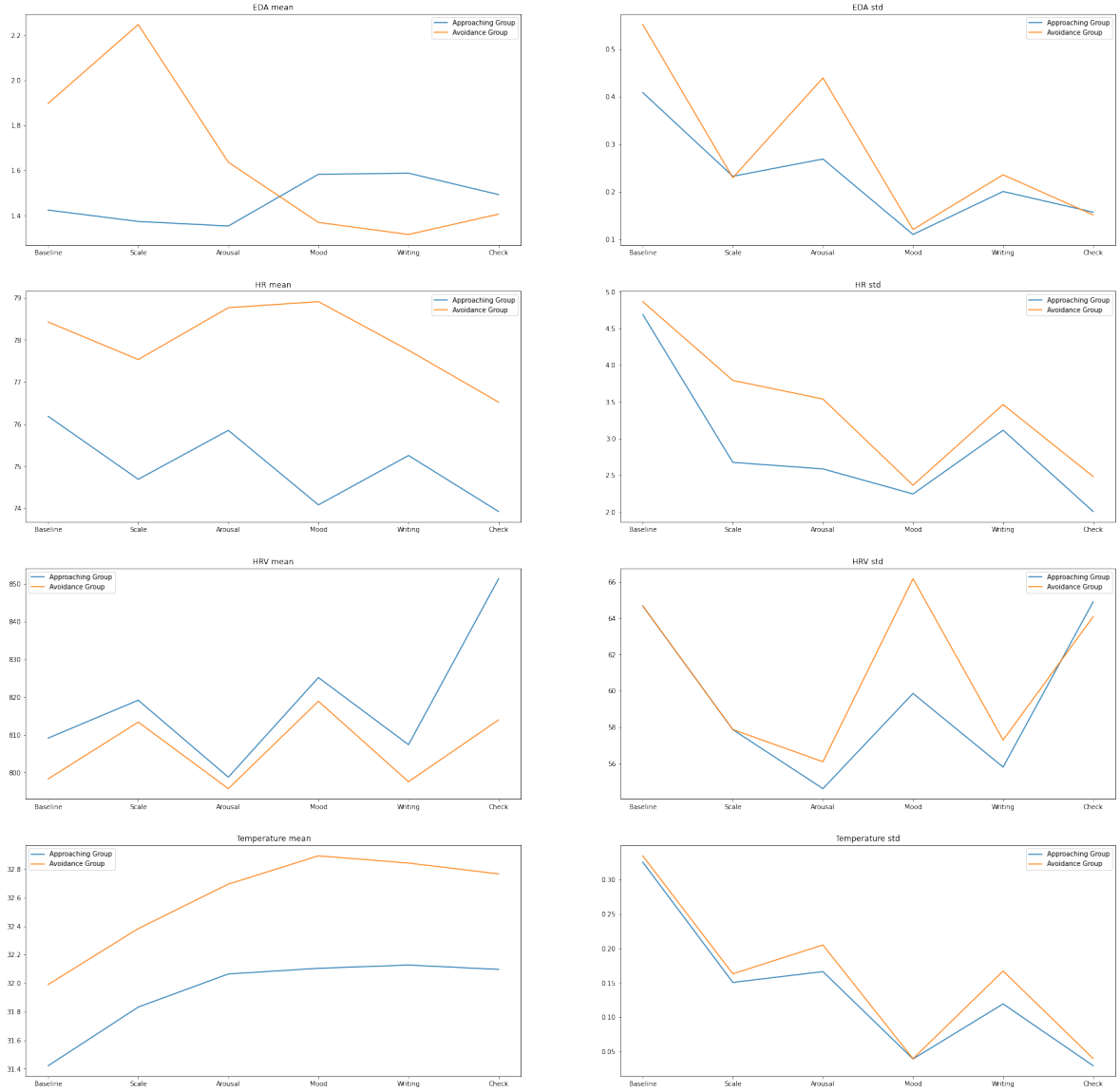

Figure B-1: Mean and Std. of All Six Phases

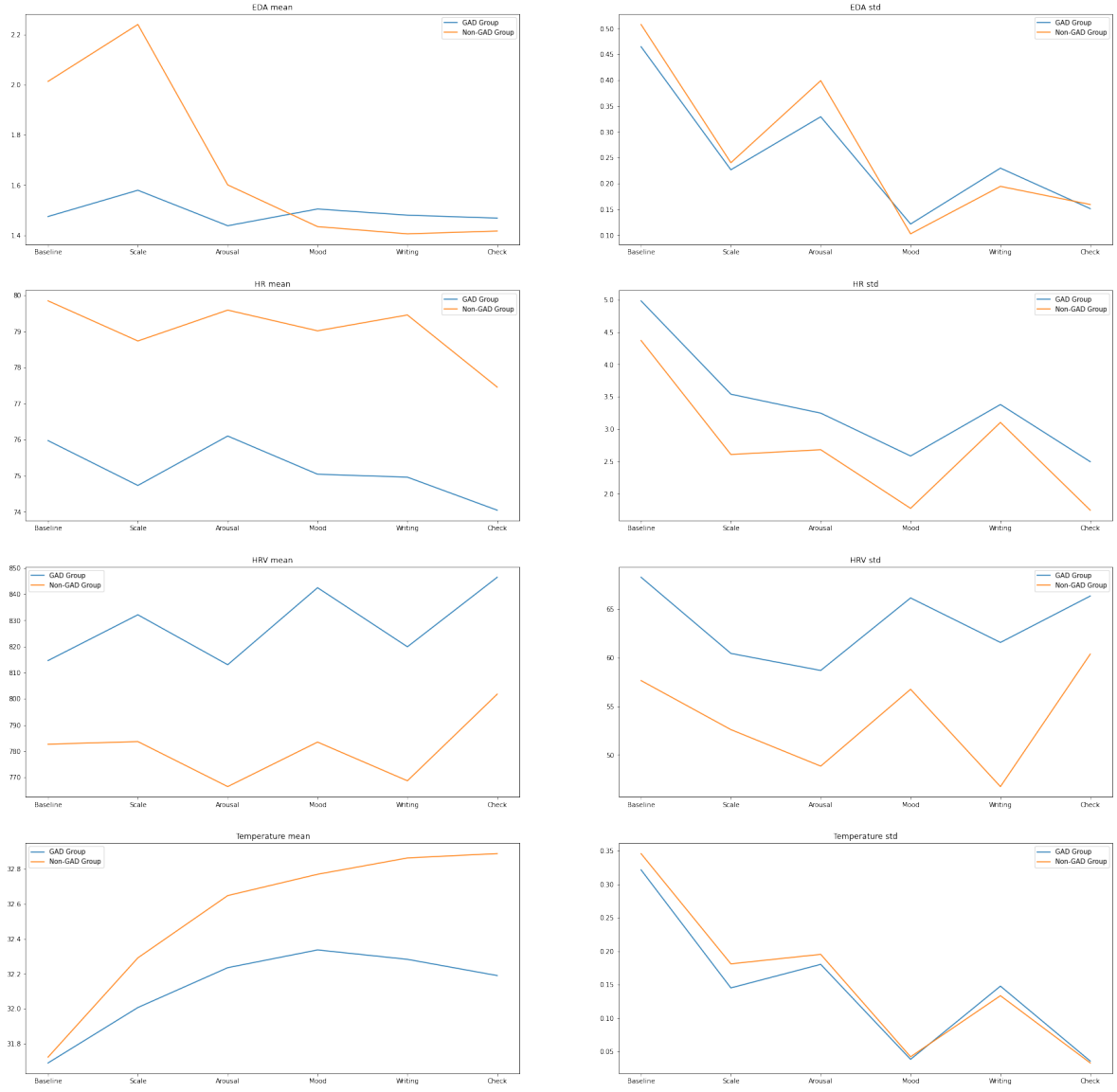

Figure B-2: Mean and Std. between GAD and Non-GAD Group

References

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional stroop phenomenon: a generic slowdown, not a stroop effect. *Journal of experimental psychology: General*, *133*(3), 323.

Al-Khatib, M., & Fletcher, C. R. (2019). Autonomic arousal in a foreign language in the context of decision making. *Proceedings of the Linguistic Society of America*, *4*(1), 24–1.

Alonso, J., Angermeyer, M., Bernert, S., Bruffaerts, R., Brugha, T., & Bryson, H. (2004). European study of the epidemiology of mental disorders [esemed] project. prevalence of mental disorders in europe: results from the european study of the epidemiology of mental disorders [esemed] project. *Acta Psychiatr Scand Suppl*, *420*, 21–27.

Andrews, G., Cuijpers, P., Craske, M. G., McEvoy, P., & Titov, N. (2010). Computer therapy for the anxiety and depressive disorders is effective, acceptable and practical health care: a meta-analysis. *PloS one*, *5*(10), e13196.

Annals of Internal Medicine. (2022). *Generalized anxiety disorder.* Retrieved from https://www.acpjournals.org/doi/10.7326/0003-4819-159-11-201312030-01006

Anxiety & Depression, Association of America. (2022). *Understand anxiety, factor & statistics.* Retrieved from https://adaa.org/understanding-anxiety/facts-statistics

APA. (1980). Diagnostic and statistical manual of mental disorders (3rd edn) dsm-iii. *Washington, DC*.

APA. (1994). Diagnostic and statistical manual of mental disorders (4th edn) dsm-iv. *Washington, DC*.

APA. (2013). Diagnostic and statistical manual of mental disorders (5th edn). *Washington, DC*.

APA. (2022a). *Apa dictionary of psychology.* Retrieved from https://dictionary.apa.org/arousal

APA. (2022b). *Apa dictionary of psychology.* Retrieved from https://dictionary.apa.org/affect

APA. (2022c). *Apa dictionary of psychology.* Retrieved from https://dictionary.apa.org/arousal-theory

Ballenger, J. C., Davidson, J. R., Lecrubier, Y., Nutt, D. J., Borkovec, T. D., Rickels, K., ... Wittchen, H.-U. (2001). Consensus statement on generalized anxiety disorder from the international consensus group on depression and anxiety. *Journal of Clinical Psychiatry*, *62*, 53–58.

Barlow, D. H. (2021). *Clinical handbook of psychological disorders: A step-by-step treatment manual*. Guilford publications.

Barnes, M., Wiles, N., Morrison, J., Kessler, D., Williams, C., Kuyken, W., ... Turner, K. (2012). Exploring patients' reasons for declining contact in a cognitive behavioural therapy randomised controlled trial in primary care. *British Journal of General Practice*, *62*(598), e371–e377.

Bartolomé-Tomás, A., Sánchez-Reolid, R., Fernández-Sotos, A., Latorre, J. M., & Fernández-Caballero, A. (2020). Arousal detection in elderly people from electrodermal activity using musical stimuli. *Sensors*, *20*(17), 4788.

Becker, K. D., Chorpita, B. F., & Daleiden, E. L. (2011). Improvement in symptoms versus functioning: How do our best treatments measure up? *Administration and Policy in Mental Health and Mental Health Services Research*, *38*(6), 440–458.

Beesdo-Baum, K., Voss, C., Venz, J., Poppenhäger, S., Berwanger, J., & Pieper, L. (2019). Worry behaviour in generalised anxiety disorder. *European Neuropsychopharmacology*, *29*, S501.

Beesdo-Baum, K., Winkel, S., Pine, D. S., Hoyer, J., Höfler, M., Lieb, R., & Wittchen, H.-U. (2011). The diagnostic threshold of generalized anxiety disorder in the community: a developmental perspective. *Journal of psychiatric research*, *45*(7), 962–972.

Boyd, R. L., Ashokkumar, A., Seraj, S., & Pennebaker, J. W. (2022). The development and psychometric properties of liwc-22. *Austin, TX: University of Texas at Austin*.

Brady, W. J., Crockett, M. J., & Van Bavel, J. J. (2020). The mad model of moral contagion: The role of motivation, attention, and design in the spread of moralized content online. *Perspectives on Psychological Science*, *15*(4), 978–1010.

Brosschot, J. F., Gerin, W., & Thayer, J. F. (2006). The perseverative cognition hypothesis: A review of worry, prolonged stress-related physiological activation, and health. *Journal of psychosomatic research*, *60*(2), 113–124.

Carl, J. R., Miller, C. B., Henry, A. L., Davis, M. L., Stott, R., Smits, J. A., ... Otto, M. W. (2020). Efficacy of digital cognitive behavioral therapy for moderate-to-severe symptoms of generalized anxiety disorder: A randomized controlled trial. *Depression and anxiety*, *37*(12), 1168–1178.

Carter, R. M., Wittchen, H.-U., Pfister, H., & Kessler, R. C. (2001). One-year prevalence of subthreshold and threshold dsm-iv generalized anxiety disorder in a nationally representative sample. *Depression and anxiety*, *13*(2), 78–88.

Carver, C. S. (2001). Affect and the functional bases of behavior: On the dimensional structure of affective experience. *Personality and Social Psychology Review*, *5*(4), 345–356.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the bis/bas scales. *Journal of personality and social psychology*, *67*(2), 319.

Caviola, L., & Faber, N. S. (2014). How stress influences our morality. *In-Mind Magazine*, *23*.

Chandra, A., & Minkovitz, C. S. (2007). Factors that influence mental health stigma among 8th grade adolescents. *Journal of Youth and Adolescence*, *36*(6), 763–774.

Charlotte, Nickerson. (2020). *How arousal theory of motivation works.* Retrieved from https://www.simplypsychology.org/arousal-theory-of-motivation.html

Chen, C.-N., Wong, J., Lee, N., Chan-Ho, M.-W., Lau, J. T.-F., & Fung, M. (1993). The shatin community mental health survey in hong kong: Ii. major findings. *Archives of general psychiatry*, *50*(2), 125–133.

Christensen, H., Griffiths, K. M., & Farrer, L. (2009). Adherence in internet interventions for anxiety and depression: systematic review. *Journal of medical Internet research*, *11*(2), e1194.

Chung, A. H., Gevirtz, R. N., Gharbo, R. S., Thiam, M. A., & Ginsberg, J. (2021). Pilot study on reducing symptoms of anxiety with a heart rate variability biofeedback wearable and remote stress management coach. *Applied Psychophysiology and Biofeedback*, *46*(4), 347–358.

Clark, L. A., & Watson, D. (1991). Tripartite model of anxiety and depression: psychometric evidence and taxonomic implications. *Journal of abnormal psychology*, *100*(3), 316.

Claus, B., & Bader, R. (2008). Processing sentences in desiderative mood affects approach/avoidance actions. In *International journal of psychology* (Vol. 43, pp. 614–614).

Cosoli, G., Poli, A., Scalise, L., & Spinsante, S. (2021). Measurement of multimodal physiological signals for stimulation detection by wearable devices. *Measurement*, *184*, 109966.

Costello, E. J., Egger, H., & Angold, A. (2005). 10-year research update review: the epidemiology of child and adolescent psychiatric disorders: I. methods and public health burden. *Journal of the American Academy of Child & Adolescent Psychiatry*, *44*(10), 972–986.

Crocq, M.-A. (2022). The history of generalized anxiety disorder as a diagnostic category. *Dialogues in clinical neuroscience*.

Croft, R. J., Gonsalvez, C. J., Gander, J., Lechem, L., & Barry, R. J. (2004). Differential relations between heart rate and skin conductance, and public speaking anxiety. *Journal of behavior therapy and experimental psychiatry*, *35*(3), 259–271.

Dale, R. (2016). The return of the chatbots. *Natural Language Engineering*, *22*(5), 811–817.

Davidson, J. R., & Dugar, A. (2010). Management of generalized anxiety disorder in primary care: identifying the challenges and unmet needs. *The Primary Care Companion for CNS Disorders*, *12*(2), 27451.

Depue, R. A., & Collins, P. F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and brain sciences*, *22*(3), 491–517.

Dyck, M. J., Jolly, J. B., & Kramer, T. (1994). An evaluation of positive affectivity, negative affectivity, and hyperarousal as markers for assessing between syndrome relationships. *Personality and Individual Differences*, *17*(5), 637–646.

El Khoury, J. R., Baroud, E. A., & Khoury, B. A. (2020). The revision of the categories of mood, anxiety and stress-related disorders in the icd-11: a perspective from the arab region. *Middle East Current Psychiatry*, *27*(1), 1–8.

Empatica Inc. (2020). *Empatica.* Retrieved from https://www.empatica.com/en-int/

Erica Cirino. (2018). *Everything you need to know about anxiety.* Retrieved from https://www.healthline.com/health/anxiety-symptoms

Estes, Z., & Adelman, J. S. (2008). Automatic vigilance for negative words in lexical decision and naming: comment on larsen, mercer, and balota (2006).

Ettman, C. K., Abdalla, S. M., Cohen, G. H., Sampson, L., Vivier, P. M., & Galea, S. (2020). Prevalence of depression symptoms in us adults before and during the covid-19 pandemic. *JAMA network open*, *3*(9), e2019686–e2019686.

Fairhurst, M. T., Löken, L., & Grossmann, T. (2014). Physiological and behavioral responses reveal 9-month-old infants' sensitivity to pleasant touch. *Psychological science*, *25*(5), 1124–1131.

Faravelli, C., Degl'Innocenti, B. G., & Biardinelli, L. (1989). Epidemiology of anxiety disorders in florence. *Acta Psychiatrica Scandinavica*, *79*(4), 308–312.

Feldman Barrett, L., & Russell, J. A. (1998). Independence and bipolarity in the structure of current affect. *Journal of personality and social psychology*, *74*(4), 967.

Fitzpatrick, K. K., Darcy, A., & Vierhile, M. (2017). Delivering cognitive behavior therapy to young adults with symptoms of depression and anxiety using a fully automated conversational agent (woebot): a randomized controlled trial. *JMIR mental health*, *4*(2), e7785.

Fowles, D. C. (1980). The three arousal model: Implications of gray's two-factor learning theory for heart rate, electrodermal activity, and psychopathy. *Psychophysiology*, *17*(2), 87–104.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of experimental psychology: General*, *130*(4), 681.

Freud, S., Strachey, J., & Freud, A. (1978). *The psychopathology of everyday life:(1901)*. Hogarth Press: Institute of Psycho-Analysis.

Friedman, R. S., & Förster, J. (2001). The effects of promotion and prevention cues on creativity. *Journal of personality and social psychology*, *81*(6), 1001.

Friedman, R. S., & Förster, J. (2002). The influence of approach and avoidance motor actions on creative cognition. *Journal of Experimental Social Psychology*, *38*(1), 41–55.

Friedman, R. S., & Förster, J. (2005). Effects of motivational cues on perceptual asymmetry: implications for creativity and analytical problem solving. *Journal of personality and social psychology*, *88*(2), 263.

Gellman, M. D. (2020). *Encyclopedia of behavioral medicine*. Springer.

Goncalves, D. C., & Byrne, G. J. (2012). Sooner or later: age at onset of generalized anxiety disorder in older adults. *Depression and Anxiety*, *29*(1), 39–46.

Gottschalk, L. A., & Gleser, G. C. (1979). *The measurement of psychological states through the content analysis of verbal behavior*. Univ of California Press.

Gould, R. A., Otto, M. W., Pollack, M. H., & Yap, L. (1997). Cognitive behavioral and pharmacological treatment of generalized anxiety disorder: A preliminary meta-analysis. *Behavior therapy*, *28*(2), 285–305.

Gray, J. A. (1970). The psychophysiological basis of introversion-extraversion. *Behaviour research and therapy*, *8*(3), 249–266.

Gray, J. A. (1987). The neuropsychology of emotion and personality. *Cognitive neurochemistry*, 171–190.

Gray, J. A. (1990). Brain systems that mediate both emotion and cognition. *Cognition & emotion*, *4*(3), 269–288.

Greden, J. F. (2003). Physical symptoms of depression: unmet needs. *Journal of Clinical Psychiatry*, *64*, 5–11.

Greenberg, P. (2018). Chatbots: Conversation for all of us. *CRM at the Speed of Light, 4th Edition; Managing Principal, The 56 Group, LLC*.

Griffiths, K. M., Farrer, L., & Christensen, H. (2010). The efficacy of internet interventions for depression and anxiety disorders: a review of randomised controlled trials. *Medical Journal of Australia*, *192*, S4–S11.

Held, J., Vîslă, A., Wolfer, C., Messerli-Bürgy, N., & Flückiger, C. (2021). Heart rate variability change during a stressful cognitive task in individuals with anxiety and control participants. *BMC psychology*, *9*(1), 1–8.

Henje Blom, E., Olsson, E., Serlachius, E., Ericson, M., & Ingvar, M. (2010). Heart rate variability (hrv) in adolescent females with anxiety disorders and major depressive disorder. *Acta Paediatrica*, *99*(4), 604–611.

Henning, E. R., Turk, C. L., Mennin, D. S., Fresco, D. M., & Heimberg, R. G. (2007). Impairment and quality of life in individuals with generalized anxiety disorder. *Depression and anxiety*, *24*(5), 342–349.

Hockey, B., & Hockey, R. (2013). *The psychology of fatigue: Work, effort and control*. Cambridge University Press.

Hoehn-Saric, R., McLeod, D. R., Funderburk, F., & Kowalski, P. (2004). Somatic symptoms and physiologic responses in generalized anxiety disorderand panic disorder: an ambulatory monitor study. *Archives of general psychiatry*, *61*(9), 913–921.

Hoehn-Saric, R., McLeod, D. R., & Zimmerli, W. D. (1989). Somatic manifestations in women with generalized anxiety disorder: Psychophysiological responses to psychological stress. *Archives of general psychiatry*, *46*(12), 1113–1119.

Hoffman, D. L., Dukes, E. M., & Wittchen, H.-U. (2008). Human and economic burden of generalized anxiety disorder. *Depression and anxiety*, *25*(1), 72–90.

Hofmann, S. G., Moore, P. M., Gutner, C., & Weeks, J. W. (2012). Linguistic correlates of social anxiety disorder. *Cognition & emotion*, *26*(4), 720–726.

Hunt, J., & Eisenberg, D. (2010). Mental health problems and help-seeking behavior among college students. *Journal of adolescent health*, *46*(1), 3–10.

Jouven, X., Schwartz, P. J., Escolano, S., Straczek, C., Tafflet, M., Desnos, M., ... Ducimetière, P. (2009). Excessive heart rate increase during mild mental stress in preparation for exercise predicts sudden death in the general population. *European heart journal*, *30*(14), 1703–1710.

Kendall, P. C. (1994). Treating anxiety disorders in children: results of a randomized clinical trial. *Journal of consulting and clinical psychology*, *62*(1), 100.

Kessler, R. C., Keller, M. B., & Wittchen, H.-U. (2001). The epidemiology of generalized anxiety disorder. *Psychiatric Clinics of North America*, *24*(1), 19–39.

Krantz, A., & Pennebaker, J. (1996). Psychological and health effects of expression on traumatic experience through dance and writing: An exploratory study. *Manuscript submitted for publication*.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. *Biological psychology*, *84*(3), 394–421.

Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: valence and arousal affect word recognition. *Journal of Experimental Psychology: General*, *143*(3), 1065.

Lader, M., & Wing, L. (1964). Habituation of the psycho-galvanic reflex in patients with anxiety states and in normal subjects. *Journal of neurology, neurosurgery, and psychiatry*, *27*(3), 210.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1990). Emotion, attention, and the startle reflex. *Psychological review*, *97*(3), 377.

Lazarus, R. S., Speisman, J. C., Mordkoff, A. M., & Davison, L. A. (1962). A laboratory study of psychological stress produced by a motion picture film. *Psychological Monographs: General and Applied*, *76*(34), 1.

Levin, A. (2017). Report details national shortage of psychiatrists and possible solutions. *Psychiatric News*, *52*(8), 1–1.

Logue, M. B., Thomas, A. M., Barbee, J. G., Hoehn-Saric, R., Maddock, R. J., Schwab, J., ... Beitman, B. D. (1993). Generalized anxiety disorder patients seek evaluation for cardiological symptoms at the same frequency as patients with panic disorder. *Journal of Psychiatric Research*, *27*(1), 55–59.

Löwe, B., Decker, O., Müller, S., Brähler, E., Schellberg, D., Herzog, W., & Herzberg, P. Y. (2008). Validation and standardization of the generalized anxiety disorder screener (gad-7) in the general population. *Medical care*, 266–274.

Lyons, M., Aksayli, N. D., & Brewer, G. (2018). Mental distress and language use: Linguistic analysis of discussion forum posts. *Computers in Human Behavior*, *87*, 207–211.

Maier, W., Gänsicke, M., Freyberger, H., Linz, M., Heun, R., & Lecrubier, Y. (2000). Generalized anxiety disorder (icd-10) in primary care from a cross-cultural perspective: a valid diagnostic entity? *Acta Psychiatrica Scandinavica*, *101*(1), 29–36.

Marrero, H., Urrutia, M., Beltrán, D., Gámez, E., & Díaz, J. M. (2017). Understanding approach and avoidance in verbal descriptions of everyday actions: An erp study. *Cognitive, Affective, & Behavioral Neuroscience*, *17*(3), 612–624.

Martin, N., Mathieu, N., Pallamin, N., Ragot, M., & Diverrez, J.-M. (2020). Virtual reality sickness detection: An approach based on physiological signals and machine learning. In *2020 ieee international symposium on mixed and augmented reality (ismar)* (pp. 387–399).

Megan Hull. (2022). *Anxiety disorders facts and statistics.* Retrieved from https://www.therecoveryvillage.com/mental-health/anxiety/anxiety-disorder-statistics/

Mewton, L., Wong, N., & Andrews, G. (2012). The effectiveness of internet cognitive behavioural therapy for generalized anxiety disorder in clinical practice. *Depression and Anxiety*, *29*(10), 843–849.

Michael, J. A., Wang, M., Kaur, M., Fitzgerald, P. B., Fitzgibbon, B. M., & Hoy, K. E. (2021). Eeg correlates of attentional control in anxiety disorders: A systematic review of error-related negativity and correct-response negativity findings. *Journal of Affective Disorders*, *291*, 140–153.

Mislevics, A., Grundspenkis, J., & Rollande, R. (2018). A systematic approach to implementing chatbots in organizations-rtu leo showcase. In *Bir workshops* (pp. 356–365).

Mohammadi, M. R., Pourdehghan, P., Mostafavi, S.-A., Hooshyari, Z., Ahmadi, N., & Khaleghi, A. (2020). Generalized anxiety disorder: Prevalence, predictors, and comorbidity in children and adolescents. *Journal of anxiety disorders*, *73*, 102234.

Moss, D., McGrady, A., Davies, T. C., & Wickramasekera, I. (2003). *Handbook of mind-body medicine for primary care.* Sage.

National Institute of Mental Health. (2022a). *Anxiety disorders.* Retrieved from https://www.nimh.nih.gov/health/topics/anxiety-disorders

National Institute of Mental Health. (2022b). *Any anxiety disorder.* Retrieved from https://www.nimh.nih.gov/health/statistics/any-anxiety-disorder

Niven, K., & Miles, E. (2012). Affect arousal. In *The encyclopedia of behavioral medicine.* Springer Nature.

Nock, M. K., & Mendes, W. B. (2008). Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. *Journal of consulting and clinical psychology*, *76*(1), 28.

North Central Behavioral Health Systems. (2022). *Dealing with situational stress.* Retrieved from https://www.ncbhs.org/blog/dealing-situational-stress

NPS Medicinewise. (2022). *Anxiety as a disorder – overlooked and undertreated.* Retrieved from https://www.nps.org.au/news/anxiety-as-a-disorder-overlooked-and-undertreated

Obrist, P. A. (2012). *Cardiovascular psychophysiology: A perspective.* Springer Science & Business Media.

Organization, W. H. (2017). *Depression and other common mental disorders: global health estimates* (Tech. Rep.). https://apps.who.int/iris/bitstream/handle/10665/254610/WHO-MSD-MER-2017.2-eng.pdf: Author.

Otim, M., Al Marzouqi, A. M., Subu, M., Damaj, N., & Al-Harbawi, S. (2021). Prevalence of generalised anxiety disorders among clinical training students at the university of sharjah. *Journal of Multidisciplinary Healthcare*, *14*, 1863.

Pennebaker, J. W. (1997). Writing about emotional experiences as a therapeutic process. *Psychological science*, *8*(3), 162–166.

Pennebaker, J. W., Francis, M. E., & Booth, R. J. (2001). Linguistic inquiry and word count: Liwc 2001. *Mahway: Lawrence Erlbaum Associates*, *71*(2001), 2001.

Pennebaker, J. W., Mehl, M. R., & Niederhoffer, K. G. (2003). Psychological aspects of natural language use: Our words, our selves. *Annual review of psychology*, *54*(1), 547–577.

Pennebaker, J. W., & Seagal, J. D. (1999). Forming a story: The health benefits of narrative. *Journal of clinical psychology*, *55*(10), 1243–1254.

Petrowski, K., Wichmann, S., Siepmann, T., Wintermann, G.-B., Bornstein, S. R., & Siepmann, M. (2017). Effects of mental stress induction on heart rate variability in patients with panic disorder. *Applied psychophysiology and biofeedback*, *42*(2), 85–94.

Picard, R. W., Fedor, S., & Ayzenberg, Y. (2016). Multiple arousal theory and daily-life electrodermal activity asymmetry. *Emotion review*, *8*(1), 62–75.

Pollatos, O., Herbert, B. M., Matthias, E., & Schandry, R. (2007). Heart rate response after emotional picture presentation is modulated by interoceptive awareness. *International Journal of Psychophysiology*, *63*(1), 117–124.

Reed, G. M., First, M. B., Kogan, C. S., Hyman, S. E., Gureje, O., Gaebel, W., ... others (2019). Innovations and changes in the icd-11 classification of mental, behavioural and neurodevelopmental disorders. *World Psychiatry*, *18*(1), 3–19.

Rehm, J., & Shield, K. D. (2019). Global burden of disease and the impact of mental and addictive disorders. *Current psychiatry reports*, *21*(2), 1–7.

Reynolds, S., Wilson, C., Austin, J., & Hooper, L. (2012). Effects of psychotherapy for anxiety in children and adolescents: A meta-analytic review. *Clinical psychology review*, *32*(4), 251–262.

Rivers, D. (2022). The situation specific arousal analyzer: Innovation in the physiological assessment of foreign language education anxiety. *Front. Educ. 7: 802639. doi: 10.3389/feduc*.

Robinson, E., Titov, N., Andrews, G., McIntyre, K., Schwencke, G., & Solley, K. (2010). Internet treatment for generalized anxiety disorder: a randomized controlled trial comparing clinician vs. technician assistance. *PloS one*, *5*(6), e10942.

Rogers, M. P., Warshaw, M. G., Goisman, R. M., Goldenberg, I., Rodriguez-Villa, F., Mallya, G., ... Keller, M. B. (1999). Comparing primary and secondary generalized anxiety disorder in a long-term naturalistic study of anxiety disorders. *Depression and Anxiety*, *10*(1), 1–7.

Rook, L. (2014). Exposure to the color red enhances creative thinking depending on appetitive-aversive cues. *Creativity Research Journal*, *26*(1), 124–130.

Rook, L., Mazza, M. C., Lefter, I., & Brazier, F. (2022). Toward linguistic recognition of generalized anxiety disorder. *Frontiers in Digital Health*, *4*.

Roth, W. T., Doberenz, S., Dietel, A., Conrad, A., Mueller, A., Wollburg, E., ... Kim, S. (2008). Sympathetic activation in broadly defined generalized anxiety disorder. *Journal of psychiatric research*, *42*(3), 205–212.

Schuerman, W. L., Chandrasekaran, B., & Leonard, M. K. (2022). Arousal states as a key source of variability in speech perception and learning. *Languages*, *7*(1), 19.

Scogin, F., Rickard, H. C., Keith, S., Wilson, J., & McElreath, L. (1992). Progressive and imaginal relaxation training for elderly persons with subjective anxiety. *Psychology and aging*, *7*(3), 419.

Siirtola, P., & Röning, J. (2020). Comparison of regression and classification models for user-independent and personal stress detection. *Sensors*, *20*(16), 4402.

Slade, T., & Andrews, G. (2001). Dsm-iv and icd-10 generalized anxiety disorder: discrepant diagnoses and associated disability. *Social Psychiatry and Psychiatric Epidemiology*, *36*(1), 45–51.

Sorg, B. A., & Whitney, P. (1992). The effect of trait anxiety and situational stress on working memory capacity. *Journal of research in personality*, *26*(3), 235–241.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: the gad-7. *Archives of internal medicine*, *166*(10), 1092–1097.

Stanley, M. A., & Novy, D. M. (2000). Cognitive-behavior therapy for generalized anxiety in late life: an evaluative overview. *Journal of Anxiety Disorders*, *14*(2), 191–207.

Starcevic, V. (2015). Generalized anxiety disorder: psychopharmacotherapy update on a common and commonly overlooked condition. *Australasian Psychiatry*, *23*(4), 338–342.

Stone, P. J., Dunphy, D. C., & Smith, M. S. (1966). The general inquirer: A computer approach to content analysis.

Support Empatica. (2021). *What should i know to use eda data in my experiment?* Retrieved from https://support.empatica.com/hc/en-us/articles/203621955-What-should-I-know-to-use-EDA-data-in-my-experiment-

Thayer, J. F., Friedman, B. H., & Borkovec, T. D. (1996). Autonomic characteristics of generalized anxiety disorder and worry. *Biological psychiatry*, *39*(4), 255–266.

Thomas, K. C., Ellis, A. R., Konrad, T. R., Holzer, C. E., & Morrissey, J. P. (2009). County-level estimates of mental health professional shortage in the united states. *Psychiatric Services*, *60*(10), 1323–1328.

Titov, N., Andrews, G., Robinson, E., Schwencke, G., Johnston, L., Solley, K., & Choi, I. (2009). Clinician-assisted internet-based treatment is effective for generalized anxiety disorder: randomized controlled trial. *Australian & New Zealand Journal of Psychiatry*, *43*(10), 905–912.

Trenoska Basile, V., Newton-John, T., & Wootton, B. M. (2022). Remote cognitive-behavioral therapy for generalized anxiety disorder: A preliminary meta-analysis. *Journal of Clinical Psychology*.

Watson, D., & Clark, L. A. (1984). Negative affectivity: the disposition to experience aversive emotional states. *Psychological bulletin*, *96*(3), 465.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the panas scales. *Journal of personality and social psychology*, *54*(6), 1063.

Watson, D., Clark, L. A., Weber, K., Assenheimer, J. S., Strauss, M. E., & McCormick, R. A. (1995a). Testing a tripartite model: I. evaluating the convergent and discriminant validity of anxiety and depression symptom scales. *Journal of abnormal psychology*, *104*(1), 3.

Watson, D., Clark, L. A., Weber, K., Assenheimer, J. S., Strauss, M. E., & McCormick, R. A. (1995b). Testing a tripartite model: Ii. exploring the symptom structure of anxiety and depression in student, adult, and patient samples. *Journal of abnormal Psychology*, *104*(1), 15.

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of personality and social psychology*, *76*(5), 820.

Waxenbaum, J. A., Reddy, V., & Varacallo, M. (2019). Anatomy, autonomic nervous system.

Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: the attention-grabbing power of approach-and avoidance-related social information. *Journal of personality and social psychology*, *78*(6), 1024.

White, J. C., Smithwick, R. H., & Simeone, F. A. (1952). *The autonomic nervous system.* LWW.

WHO. (2022). *Icd-11 2022 release.* Retrieved from https://www.who.int/news/item/11-02-2022-icd-11-2022-release

WHO, W. H. O. (2022). International classification of diseases 11th revision. *WHO, World Health Organization*.

Wittchen, H.-U. (1996). Critical issues in the evaluation of comorbidity of psychiatric disorders. *The British Journal of Psychiatry*, *168*(S30), 9–16.

Wittchen, H.-U. (2002). Generalized anxiety disorder: prevalence, burden, and cost to society. *Depression and anxiety*, *16*(4), 162–171.

Wittchen, H.-U., Kessler, R. C., Beesdo, K., Krause, P., & Hoyer, J. (2002). Generalized anxiety and depression in primary care: prevalence, recognition, and management. *The Journal of clinical psychiatry*, *63*(suppl 8), 7712.

Wittchen, H.-U., Nelson, C. B., & Lachner, G. (1998). Prevalence of mental disorders and psychosocial impairments in adolescents and young adults. *Psychological medicine*, *28*(1), 109–126.

Wittchen, H.-U., Zhao, S., Kessler, R. C., & Eaton, W. W. (1994). Dsm-iii-r generalized anxiety disorder in the national comorbidity survey. *Archives of general psychiatry*, *51*(5), 355–364.

Zajenkowski, M. (2013). Energetic arousal and language: Predictions from the computational theory of quantifiers processing. *Human factors*, *55*(5), 924–934.

Zevon, M. A., & Tellegen, A. (1982). The structure of mood change: An idiographic/nomothetic analysis. *Journal of personality and social psychology*, *43*(1), 111.