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A Personalized Approach to Understanding Human Emotions

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A Personalized Approach to Understanding Human Emotions

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Abstract. In this paper we present the relationship between stress and emotions. While there exists copious amounts of research into stress and its contribution to our overall well-being, very little research has been done in understanding which emotions relate to stress. Through the use of self-reported questionnaires, we analyze individual responses during stress-induced and pleasant experiences. We show how some emotions that accompany stress vary by individual. Previous studies focus primarily on the physiological response as the leading indicator to stress [3]. However, most people are not instrumented in their daily lives making multiple wearable sensors unreasonable as a stress detector. Emotions are always present and cannot be disconnected from the physiological symptoms of stress. By better understanding these emotions we can identify situations where stress is likely to occur thereby allowing better management. We examine ethical concerns with exploiting this knowledge and how technology may be used to learn a persons emotion and ways in which this is already being used in research and marketing. We conclude that stress is an exciting condition for all subjects but the underlying emotions and whether those are positive or negative vary by individual. This suggests that a personalized model would be best at identifying those conditions which lead to a physiological stress response.

1 Introduction

The signs of stress can be found in both physical and mental forms. In the former, hormones are released during times of stress that are the same as those responsible for our fight or flight response mechanism [17]. Physiological responses, such as increased heart rate and rapid breathing, are mechanisms that have evolved and served as key ingredients to our survivability. However, maintaining elevated levels of stress often lead to the development of negative health conditions.

While these physiological impacts of stress are broadly known, the emotional response to stress is not well studied. Emotions impact our perceptions of the world around us [18]. The proper management of stress cannot be achieved unless we understand the relationship that exists between the physiological stress response and the individualistic set of emotions that accompany it. In our study we look at 15 subjects that were placed under stress and non-stress situations. We explore physiological responses that accompany the stress-related conditions and thru the use of self-assessments explore the individual feelings and emotions that accompanied each subject in stress and other non-stress situations.

Stress is a very broad description that is accompanied by a variety of different emotions. How each person deals with various situations is just one of the many things that make us unique individuals. What may be stressful to one person may result in a completely different response for another. While there are some commonly reported contributors to stress, such as driving in heavy traffic and public speaking, the response to potential triggers will vary by individual. Our past experiences, in part, shape how we deal with situations and the emotions that come along with them.

We evaluated the emotions of the subjects in our study and look at how stress and non-stress conditions relate to positive and negative feelings. Some aspects of stress can be motivating and elicit a feeling of stimulation and engagement other feelings are associated with distress and worry. It's the negative emotions, left unhindered and sustained, that lead to chronic health conditions such as obesity, heart disease, depression, anxiety, and other conditions brought on by a weakened immune system [1].

Current methods of identifying stress in an individual depend on an evaluation of physical and emotional symptoms and tests. The National Center for Biotechnology Information (NMBI) wrote that the best method for diagnosing this complex condition includes a variety of methods with a "thorough, stress-oriented, face-to-face medical interview" being the most practicable method [13]. The interview is intended to identify stress, after the fact by asking questions about how we feel at the moment or during the event itself. Our ability to identify applicable events that lead to a stressful state of mind depend on our own recollection of those events. However, studies show that stress is an important influencer to learning and the memory process itself [2]. Our research seeks to better link our emotions to the physiological stress response so that behaviors that lead to negative emotions can be impacted in the early stages.

In our research we saw commonalities across some of the broad categories that are used to define regions where stressful conditions may exist. While under a stress-related condition we saw the highest levels of positive and negative emotions, however the emotions associated with that condition varied by individual. While one person felt their level of interest increased during stress, another felt considerably less interested. And while one felt more guily during stress, another felt less guilty. While we examined only 15 subjects from a single research facility and cannot infer these results to a wider audience, the data suggests that a model may consistently capture an increase in positive or negative feelings but our individual experiences have encoded the emotions associated with those feelings in a very individual manner.

2 WESAD Study

The purpose of the study was to collect data on the subjects while under a neutral, stress, and amusement state of mind. Subjects were asked to refrain from caffeine and tobacco one hour before the experiment began. In addition, they were asked not to perform strenuous exercise the day of the study.

A 20 minute baseline condition was initially recorded with subjects either sitting or standing and neutral reading material was provided. The amusement condition was induced by having the subjects watch eleven video clips. The video clips were chosen from the corpus presented by Samson et al [4]. The stress condition used the Trier Social Stress Test (TSST) [5], an effective test that consists of a public speaking portion and mental arithmetic. Both these tests are known to reliably elicit a stress response [6]. A 10 minute rest period was given after the stress condition. In addition, a guided meditation period was used following the rest period and amusement protocol. This was intended to reduce the excitement levels of the subjects.

There were two variations regarding the order in which the study protocols were applied. The following protocol conditions were applied as either baseline, amusement, meditation, stress, meditation or baseline, stress, meditation, amusement, meditation. In total, the study lasted approximately 2 hours.

At the completion of each of the protocol conditions the subjects were asked to complete several self-assessment questionnaires. These self-assessments included the Positive and Negative Affect Schedule (PANAS), a shortened Spielberger State-Trait Anxiety Inventory (STAI), the Self-Assessment Manikins (SAM) for valence and arousal, and a shortened Short Stress State Questionnaire (SSSQ).

3 Emotional Persuasion

Emotion and persuasion go hand-in-hand. We can see evidence of this by examining a experiment which demonstrates the persuasive power of "free". In this experiment subjects were asked to choose from either a free $10 gift card or pay $7 for a $20 gift card. The rational mind would choose to receive $13 free, however more subjects chose the $10 gift card [1]. The connection between emotion and persuasion is a relationship that advertisers have been exploiting for some time [19].

4 Valence and Arousal

Valence and arousal are two broad categories for which most emotional experiences can be categorized. Valence is a measure of how positive or negative an experience is while arousal measures how exciting or calming information is

[1] https://conversionxl.com/blog/emotional-persuasion-guide

perceived [2]. Public speaking and hearing strange noises in the night are examples of situations that typically result in high arousal emotion. Valence is the mechanism which encodes that experience as either positive or negative.

The aforementioned two system mind describes the concept of an automatic part of the brain that acts on impulses in an unconscious way. The reptilian complex is an area of the brain responsible for vital body functions such as heart rate, breathing, body temperature and balance. Our instincts originate from this part of the brain and cause us to focus attention on the high-arousing emotional stimuli. A specific region in the brain known as the reticular activating system (RAS) is responsible for controlling arousal. The RAS is akin to a network that does not interpret signals but rather is responsible for activating entire areas of the cerebral cortex by forming connections between the brainstem, brain, and spinal cord [3]. It's the increased levels of arousal that wake up the brain and prepare it for interpretation of the signals it's about to receive. Our ability to control our emotions depend, in part, upon biochemical response mechanisms that play critical roles in managing our levels of arousal.

Emotional arousal also plays a significant role in our ability to recall events. The introduction of emotion on memory can be used in a positive manner but more often it has a negative effect by reducing our ability to process new information and inhibits the utilization of cues [9]. A phenomenon known as "weapon focus" refers to the concentration a person places on the weapon itself when witnessing a crime that leaves other information and specific details harder to retrieve from memory. In one experiment, subjects were put into two groups and shown a series of images depicting one of two scenarios. In one, a customer was seen pointing a gun at a cashier and in the other group the image showed a customer handing the cashier a check. Memory of the subjects were tested after seeing the images and the group that was shown the image of the gun had poorer memory [10].

5 Physiological Stress Responses

Traditional methods of identifying stress rely upon the use of behavioral evaluations. Many people describe stress as an overwhelming feeling that's often accompanied by worry and a general rundown feeling [4]. Stress can be defined as "a negative emotional experience accompanied by biochemical, physiological and behavioral changes [11]." Psychophysiology is a branch of psychology that deals with the relationship between mental and physical processes. The associations with physiological responses and behaviors are often associated within the realm of behavioral neuroscience but psychophysiology more accurately describes these studies. The focus of psychophysiology is on psychological, social, and behavioral

[2] https://conversionxl.com/blog/valence-arousal-and-how-to-kindle-an-emotional-fire/
[3] https://integratedlistening.com/meet-the-reticular-activating-system-ras/
[4] https://www.apa.org/helpcenter/understanding-chronic-stress

phenomena and the recognition of physiological responses [5]. While emotions are sometimes perceived as something "inside our heads" the physical manifestations are prominent as well and can be seen by activation of the sympathetic division of the autonomic nervous system. The physical manifestations of stress on our body allow objective measurements and we explore several ways that sensors can be used to capture some of these physical properties.

Furthermore, while an American Psychological Association (APA) report showed that more than 70% of Americans reported feeling physical and psychological symptoms of stress on a regular basis only 17% of those with significant stress said they were managing it very well.

5.1 ECG

An electrocardiogram (ECG) is a test commonly used by physicians to measure the amount of electrical activity in the heart. The output of the test is a signal that records a continuous line graph and is often used to diagnose various heart related conditions. Heart activity is closely related to physiological and psychological arousal. This close relationship makes ECG a valuable indicator for assessing and understanding our mental state [6]. We see this demonstrated in Figure 1 which indicates the ECG tracing from one of our subjects. The data shows approximately 5 seconds while under four different emotional states. Of the four conditions, stress indicates the most rapid heartbeat and the amplitude is significantly lower than the other conditions.

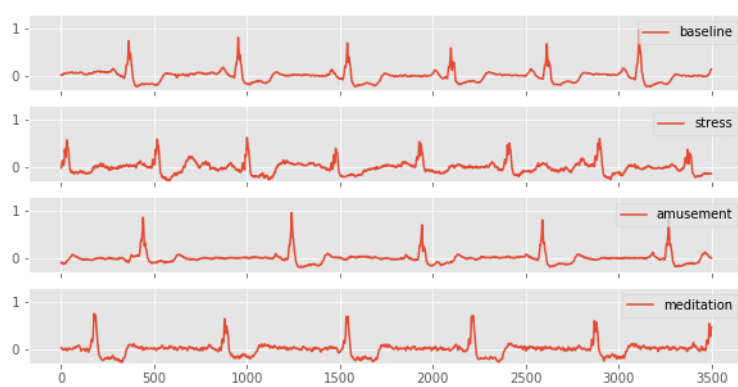

Fig. 1. Heart rate (ECG) while under different emotional states

[5] https://imotions.com/blog/psychophysiology/
[6] https://imotions.com/blog/what-is-ecg/

5.2 EDA

Electrodermal activity (EDA) measures changes in the electrical properties of skin in response to sweat secretion. Changes in skin conductance are gathered by applying a constant low voltage. These changes in electrical conductivity provide an indication of sympathetic nervous system arousal and provide insight into the psychological state of a subject. EDA response has been shown to be a robust within-subject indicator of stress response but is highly variable as a between-subject response [14]. Figure 2 shows the distribution of EDA values for one subject. We can see that the distribution of values for stress is distinctly different than meditation and amusement but overlaps significantly with the baseline condition.

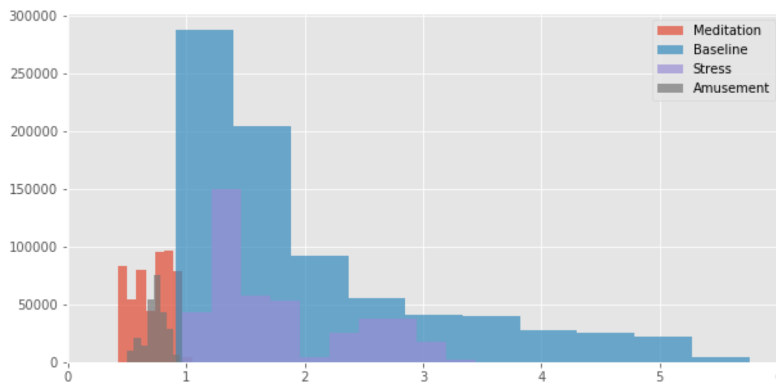

Fig. 2. Average values of electrodermal activity (EDA) while under different emotional states

5.3 EMG

Electromyogram (EMG) measures the amount of electrical activity in muscles. When muscles are more active, electrical current increases. When at rest, an EMG would not normally show any muscle activity. Figure 3 indicates the EMG signal for a single subject. The data is centered around zero indicating non-movement much of the time. Increased EMG activity has been shown to be associated with a stress stimulus [15].

5.4 Temperature

Temperature of the body has also been shown to be affected by stress. However, studies have shown that measurement location plays a crucial role in the amplitude and direction of the stress-induced temperature change [16]. Figure 4 shows

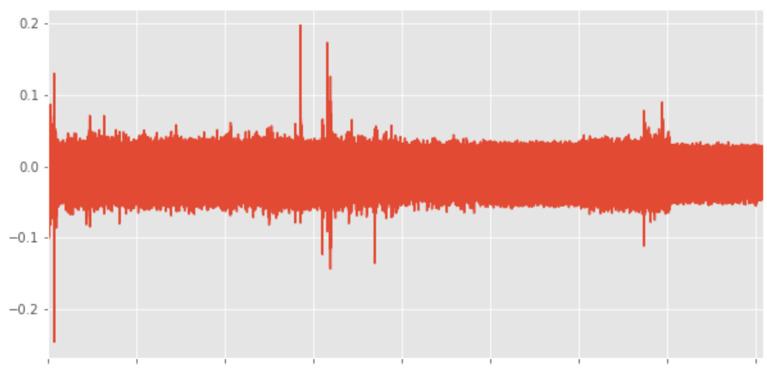

Fig. 3. Electromyogram (EMG) values indicating no muscle movement (0 value) and muscle movement

the distribution of body temperatures of the subjects for each of the 4 protocol conditions. Body temperatures during the stress condition are approximately 2.5 degrees higher than the baseline condition and approximately 1 degree lower than amusement. Temperature values during the meditation condition are split with some having average values close to amusement and others overlapping with the stress condition.

5.5 Respiration

Stress has also been associated with changes in the respiratory system. Changes such as shortness of breath and rapid breathing have been found to occur with strong emotions [7]. Normal respiration in adults is approximately 12 breaths/min. The plot below shows 15 seconds of respiration. Inhalation can be seen by the rising values while exhalation by falling values. Figure 5 shows more consistent breathing patterns in the amusement and meditation conditions. The stress condition has considerably more variation in amplitude (note the difference in y-axis).

6 WESAD Dataset

The Wearable Stress and Affect Detection, or WESAD dataset [3], was provided as a publicly available dataset from the University of California, Irvine (UCI) Machine Learning Repository. The WESAD study was comprised of 17 subjects however only 15 subjects yielded usable data due to sensor malfunctions. The

[7] https://www.apa.org/helpcenter/stress/effects-respiratory

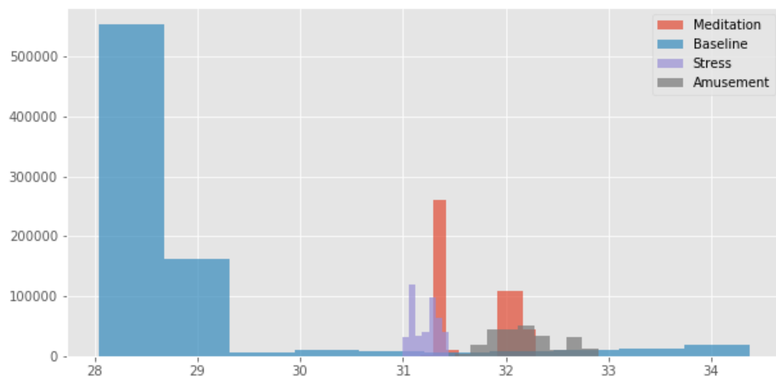

Fig. 4. Average body temperature while under different emotional states

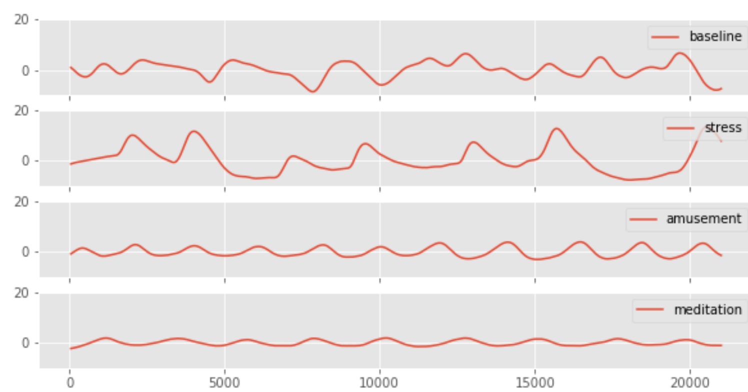

Fig. 5. Respiration while under different emotional states

subjects were graduate students at a research facility. Various criteria were used to exclude subjects from the study and included pregnancy, heavy smoking, mental disorders, and any cardiovascular or chronic conditions. Three subjects were female and twelve were male with a mean age of 27.5 years.

Two devices were worn which captured physiological data. The chest-worn device was a RespiBAN Professional and captured three-axis acceleration (ACC), respiration (RESP), electrocardiogram (ECG), electrodermal activity (EDA), electromyogram (EMG), and temperature. Table 1 shows the summary statistics for the RespiBAN device. All signals from the RespiBAN device were sampled at 700 Hz. The wrist-worn device was an Empatica E4 and captured EDA at 4 Hz, ACC at 32 Hz, temperature at 4 Hz, and blood volume pulse (BVP) at 64 Hz. Table 2 shows the summary statistics for the Empatica device.

Table 1. RespiBAN Summary Statistics

	ACCx	ACCy	ACCz	ECG	EMG	EDA	Temp	Resp
mean	0.8117	-0.0442	-0.2590	0.0011	-0.0030	4.8882	33.9049	0.0543
std	0.1313	0.1039	0.3322	0.2687	0.0179	3.5312	1.2169	4.0991
min	-6.6000	-6.6000	-6.6000	-1.5000	-1.5000		-273.1500	-50.0000
25%	0.7598	-0.0798	-0.4652	-0.0917	-0.0102	2.3289	33.6140	-2.0645
50%	0.8622	-0.0310	-0.2520	-0.0260	-0.0027	3.7193	34.1703	-0.1984
75%	0.9010	0.0154	-0.0676	0.0330	0.0043	7.0576	34.6171	2.1713
max	2.9814	1.6090	4.5082	1.5000	1.4643	22.4110	35.7781	38.8001

Table 2. Empatica Summary Statistics

	ACCx	ACCy	ACCz	BVP	EDA	Temp
mean	11.6619	-2.2735	17.7081	-0.0101	1.8018	32.5981
std	44.1114	28.1481	29.7541	65.3020	2.3433	1.4981
min	-128.0000	-128.0000	-128.0000	-1671.8300	0.0451	28.9700
25%	-36.0000	-19.0000	-2.0000	-14.9300	0.3360	31.5500
50%	26.0000	-1.0000	17.0000	2.1600	0.8307	32.7100
75%	51.0000	12.0000	43.0000	16.2400	2.3960	33.6800
max	127.0000	127.0000	127.0000	1409.9400	15.9215	35.9700

7 Analysis of Survey Results

7.1 Self-Assessment Manikins for valence and arousal

The Self-Assessment Manikins for valence and arousal (SAM) is a pictorial assessment technique that measures pleasure, arousal, and dominance associated with an individuals reaction to a stimuli. The SAM was administered upon the completion of each protocol condition in order to generate labels in the valence-arousal space. Valence and arousal were both measured using a 9 point scale with 1 representing low valence/arousal and 9 high valence/arousal.

A kernal density estimation (KDE) plot was used to show the differences in scores between protocol conditions with valence scores for all subjects plotted along the x-axis and arousal scores along the y-axis. In Figure 6 the scores following baseline and stress conditions are plotted and we can see a tight distribution for the baseline condition with valence scores around 7 and arousal scores around 2. Scores following the stress condition were distinctively different for most subjects with valence scores approximately 3.5 to 5 and arousal scores centered around 7 to 8. We see more variation in scores around stress than the baseline condition indicating more individual variation to the stress stimuli used in the study.

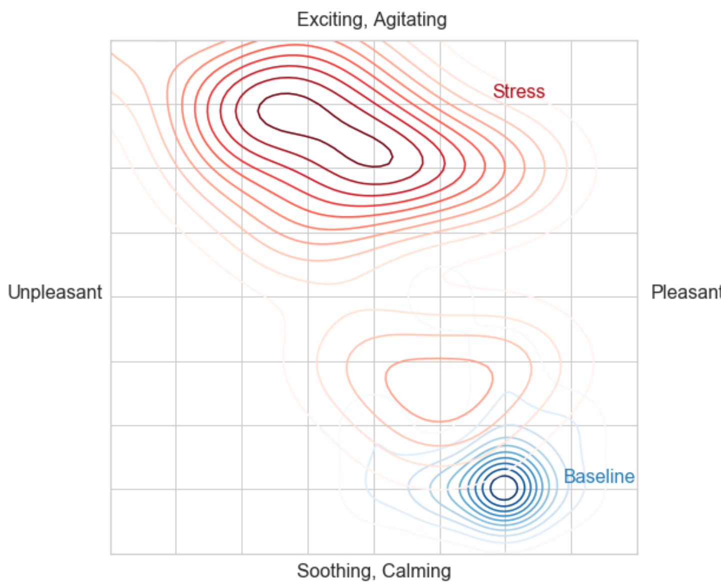

Fig. 6. Valence (x-axis) and Arousal (y-axis) scores while under stress and baseline emotional states

In Figure 7 we see changes between the amusement and meditation conditions. Changes for these two emotional states were much less pronounced than changes for stress. Amusement scores for valence are centered around 1 point higher and arousal scores closely resemble those of the baseline condition with a score of 2, however we see that some subjects rated their arousal score several points higher.

The meditation protocol, designed to bring subjects back to a neutral state of mind, appear to be effective. Scores shown in Figure 7 very closely resemble those of the baseline condition with valence having a similar width distribution but with arousal scores very narrowly centered around a value of 2. This suggests that the guided meditation was very effective at reducing excitement levels in all subjects.

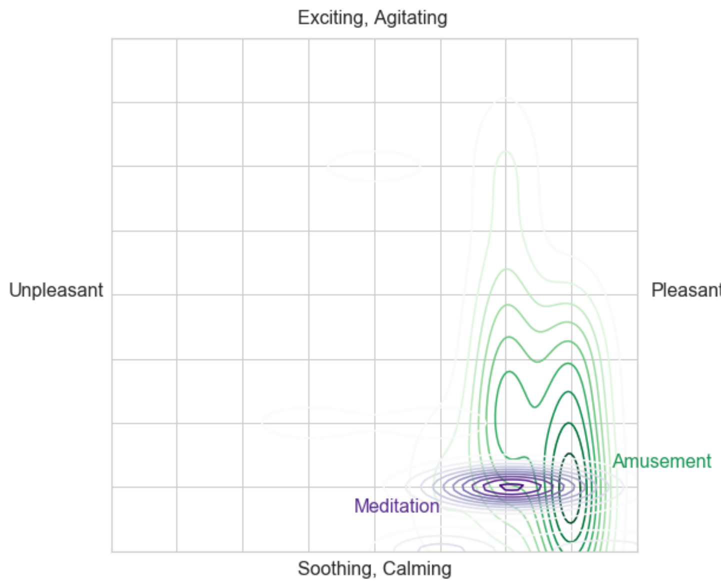

Fig. 7. Valence (x-axis) and Arousal (y-axis) scores while under meditation and amusement emotional states

7.2 Positive and Negative Affect Schedule

The Positive and Negative Affect Schedule (PANAS) is a 20 question self-administered survey that has two 10-item terms that measure positive and negative affect. Each question is rated on a 5 point Likert scale ranging from 1 (i.e. not at all) to 5 (i.e.very likely). The total of each represent the subjects mood at the time. We use the change between condition protocols to understand how each individuals mood was affect by the protocol conditions.

Figure 8 indicates the scores (y-axis) for each protocol condition (x-axis) with positive scores shown first for each condition. The order of conditions shown are as follows: Baseline, Stress, Meditation (first occurrence), Amusement, and Meditation (second occurrence). Note that this does not reflect the order in which the conditions actually occurred for all subjects. Positive and negative scores following the baseline protocol had median scores of 26 and 12 respectively. After the stress condition, scores for both terms increased to a median of 30 for positive and 18 for negative terms. Scores for other protocol conditions are listed as well and, with the exception of the stress condition, all show a decrease from the baseline protocol. Negative scores for meditation and amusement had several scores of 10, which represent the lowest possible score.

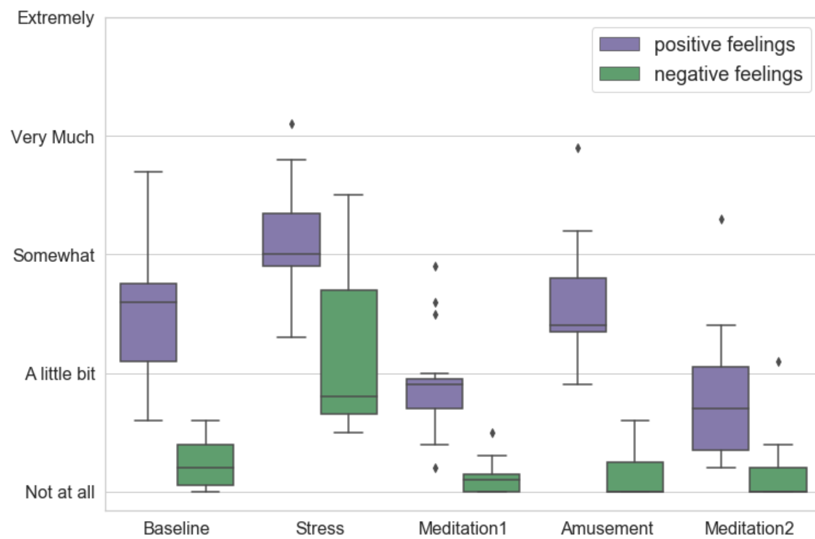

Fig. 8. Change in positive and negative feelings between emotional states

In Figure 9 we show how each positive term changed from the baseline to the stress condition. Each colored dot is associated with a specific positive term (y-axis) and the difference (x-axis) indicates the change from baseline to stress. The largest decrease was associated with the term ”enthusiastic” with approximately 47% (i.e. 7) subjects experiencing a decrease of 1-point and a single subject reporting a 3-point drop. Perhaps more significant was the increase in positive scores with all subjects reporting an increase in the ”active” term with approximately 73% reporting a 2-3 point increase. The terms ”active, excited, proud, alert” were the only terms that had no decrease in score.

In Figure 10 we show how each negative term changed from the baseline to the stress condition. Unlike the positive terms where many decreases were reported, there were only 6 instances where the negative feeling decreased. The largest and most consistent change was in the term ”nervous” where all subjects reported an increase and over half reporting a 3-4 point increase. The terms ”guilty” and ”hostile” changed the least across all subjects, however we can see how each subject interpreted the conditions differently as one subject felt more guilty (+2 points) while another less guilty (-2 points).

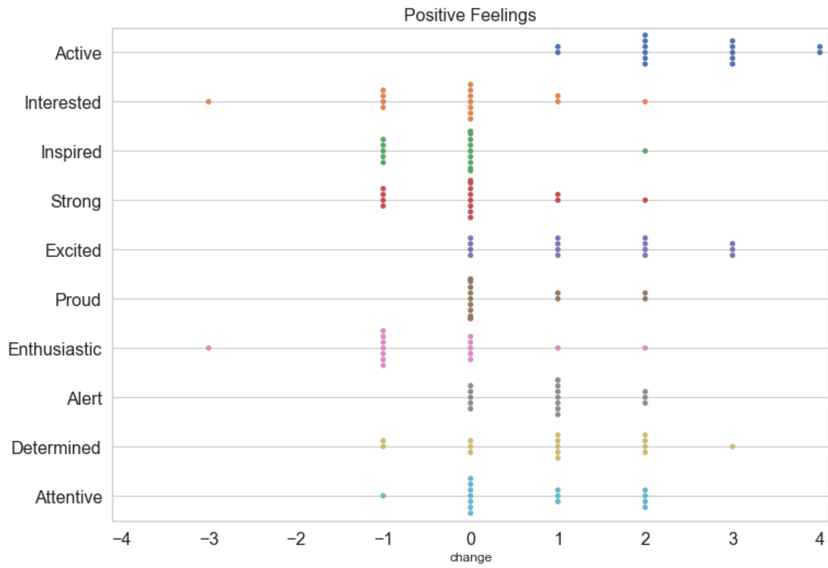

Fig. 9. Change in positive emotions from baseline to stress

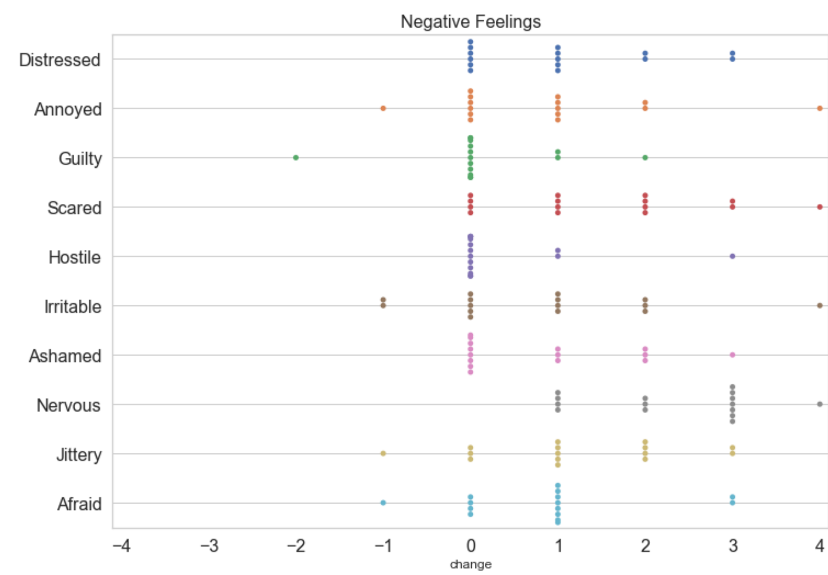

Fig. 10. Change in negative emotions from baseline to stress

7.3 Spielberger State-Trait Anxiety Inventory

The Spielberger State-Trait Anxiety Inventory (STAI) administered was a 6-item questionnaire that contains various statements assessed on a 4-point Likert scale. The shortened STAI was used to gain insight into the anxiety level of each subject. A 'normal' score is approximately 34-36 [12]. Mean scores shown in Figure 11 indicate all conditions with the exception of stress scoring within the normal range.

Of the 6-items half were associated with positive items whereas the other half negative items. The positive items asked subjects to rate their feelings with regard to the following: calm, relaxed, and content. Negative items including the following: tense, upset, and worried.

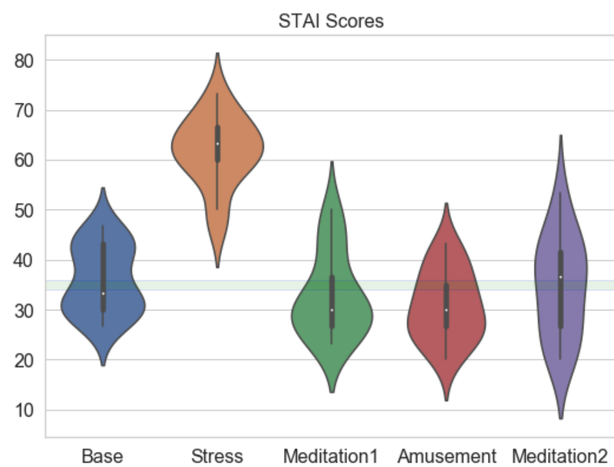

Fig. 11. Scores indicating the stress stimulus were effective at inducing stress

7.4 Short Stress State Questionnaire

The original Short Stress State Questionnaire (SSSQ) is a 24-item SSSQ. This shortened 9-item SSSQ was similar to the full length in that it was designed to measure 3 areas: Task Engagement, Distress, and Worry. There were 3 questions taken from each of the topic areas and, unlike the other questionnaire which were completed after each condition, this questionnaire was only taken after the stress condition.

Figure 12 shows the scores for each subject across the 3 areas. The questions associated with distressing feelings scored the highest with a mean score of 11.7 followed by feelings of worry with a mean score of 10.6.

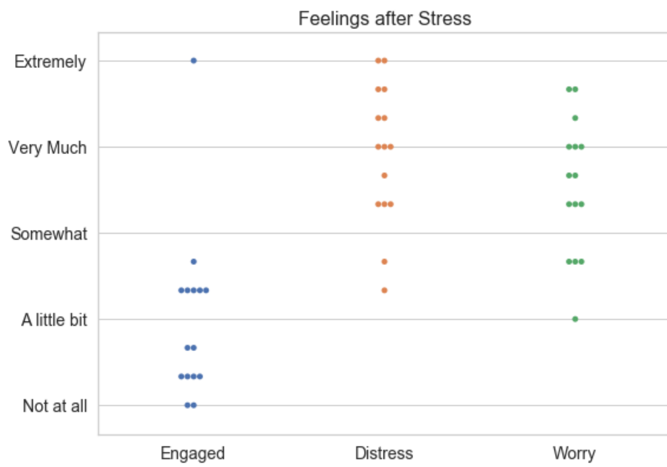

Fig. 12. How subjects felt after stress

8 Wearable Devices for Monitoring Emotions

There is a currently large interest in the commercial development of wearable devices. There have been more than $200 million invested by venture capitalists in mental health related apps [8]. Some of those wearable devices being sold today have sensors that monitor breathing rate, heart rate variability, and skin temperature. A company known as Spire Health has a device that they claim has proven to help with stress and anxiety. Their device is designed to measure the expansion and contraction of the torso to infer breathing patterns. These patterns are used to provide responses via an app to the user about how they may be feeling with responses such as calm, tense, or focused. The idea being that a notification can prompt the user to take an action (i.e. slow breathing technique) that may help reduce stress.

A recent news article brought awareness of a device that Amazon is currently developing that can recognize human emotions [9]. The wrist-worn device is designed to be paired with an app and essentially infers the users emotions from the sound of their voice. It was suggested that the device may eventually be used to help people more effectively communicate with one another. Amazon is just one of many companies seeking to develop technologies that derive a persons emotional state. The techniques vary from company to company and product to product with emotional states being derived from images, audio data, and

[8] https://www.outsideonline.com/2332386/stress-trackers-wearables-relaxation
[9] https://www.bloomberg.com/news/articles/2019-05-23/amazon-is-working-on-a-wearable-device-that-reads-human-emotions

other inputs. The general term associated with these computing technologies is affective computing.

Affective computing technology deals with the development and study of systems and devices that can learn a persons emotional state of mind. Human-computer interaction has adapted over time from use as a desktop aid in work-place environments to changes in how we communicate and interact socially. As our interactions with technology becomes more deeply ingrained in our daily lives for these interactions to become more natural and genuine there must be an understanding the impact of emotions has on our behavior.

9 Ethics

The ability to develop devices that can not only detect a persons emotions but affect their decisions should be approached with great responsibility. Today our decisions are already affected by integration of computing technology into our daily lives. Virtually all of us have cell phones, browse social media, or use apps that collect data about us that include our personal preferences, our location, and potentially sensitive personally identifiable information. How this data is used is not always clear. Laws vary by location within European laws being more strict, the US lags in many cases to implement laws that properly protect consumers of such devices.

The development of wearable devices that can understand emotions expose even larger amounts of sensitive data. Many of the devices that are beginning to introduce features that center around stress and emotions fall into a category of devices known as fitness tracking devices. The data from these devices are not subject to federal health care privacy laws like the Health Insurance Portability And Accountability Act (HIPAA) [10]. It is essential that users understand just what information is being collected, how this information is being used, to whom it may be shared with, and what rights you may or may not have to delete such information.

While data scientist should always strive to maintain the highest degree of ethical standards, we must be concerned about how our personal data may be used by those that don't ascribe to such ethical standards. Unfortunately, data breeches seem to be a common occurrence nowadays. Even if companies agree to use data collected from you in a responsible manner, to what extent to other companies need to follow those same standards. If your data, for instance, gets into the hands of an insurance company are they then free to assess higher premiums from those more likely to have higher stress because higher stress correlates to more occurrences of disease?

As computing technologies integrate more into our day-to-day lives, reading our emotions, deriving our feelings, we must first ask these difficult questions and make sure appropriate ethical standards are place before profit. Commercialization of these devices will not wait on governments to develop appropriate

[10] https://www.outsideonline.com/2332386/stress-trackers-wearables-relaxation

standards. It becomes extremely important for the data scientist who are at the forefront of the development of these technologies to step up and ensure these difficult questions are answered.

10 Conclusions

We reviewed the WESAD dataset and looked at how various physiological stress responses change between stress and non-stress conditions. We saw that physiological indicators can provide a reliable indicator of a stress response but accuracy of these results may be affected by placement location. We saw that wearable technologies are emerging that use the relationships between stress and physiological changes to infer a persons emotions and feelings. While sensors worn in a lab environment have the ability to discern physiological changes we are often not even conscious of, it's not practical to wear some them in our day-to-day life. Therefore, the wearable devices of today will likely have limitations.

We saw that people under a stressful conditions exhibit an increased level of excitement and while overall stress has a negative affect we saw changes in both positive and negative feelings. These changes in emotions vary by individual. While wearable devices use changes in physiological responses to infer our emotional state these rely on some commonalities. We saw these common changes in emotions such as "active" and "nervous". We also so a persons response to stress differed with some feeling more engaged and others more distressed. This suggests certain emotions can only be predicted with the use of personalized models.

These new technologies are venturing into unknown territory and we highlighted some of the ethical concerns with being able to learn a persons feeling. In today's world were technology is quick to change and adoption of new laws to protect a persons privacy and personal information often comes after the technology has been put to use, we have a high degree of responsibility to ensure ethical practices are considered from inception.

References

1. Samuel Brod, Lorenza Rattazzi, Giuseppa Piras, Fulvio D'Acquisto. 'As above, so below' examining the interplay between emotion and the immune system. https://doi.org/10.1111/imm.12341
2. Carmen Sandi, M. Teresa Pinelo-Nava. Stress and Memory: Behavioral Effects and Neurobiological Mechanisms https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1950232/
3. Philip Schmidt, Attila Reiss, Robert Duerichen, Claus Marberger and Kristof Van Laerhoven. 2018. Introducing WESAD, a multimodal dataset for Wearable Stress and Affect Detection. In 2018 International Conference on Multimodal Interaction (ICMI 18), October 16 20, 2018, Boulder, CO, USA. ACM, New York, NY, USA, 9 pages.
4. A. Samson, S. Kreibig, and J. Gross. Eliciting positive, negative and mixed emotional states: A film library for affective scientists. Cognition and Emotion 30, 5(2016), 827-856.

5. C. Kirschbaum, K. Pirke, and D. Hellhammer. 1993. The Trier Social Stress Test - a tool for investigating psychobiological stress responses in a laboratory setting. Neuropsychobiology 28, 1-2 (1993), 76-81.
6. K. Plarre, A. Rajj, and M. Scott. 2011. Continuous inference of psychological stress from sensory measurements collected in the natural environment. In 10th International Conference on Information Processing in Sensor Networks (IPSN). 97-108.
7. Evans, J. S. B. T., and Frankish, K. (Eds.). (2009). In two minds: Dual processes and beyond. New York, NY, US: Oxford University Press. http://dx.doi.org/10.1093/acprof:oso/9780199230167.001.0001
8. Daniel Kahneman. (2011) Thinking Fast and Slow. New York: Farrar, Straus and Giroux
9. Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. Psychological Review, 66(3), 183-201. http://dx.doi.org/10.1037/h0047707
10. Loftus, E.F., Loftus, G.R. & Messo, J. Law Hum Behav (1987) 11: 55. https://doi.org/10.1007/BF01044839
11. Baum, A. (1990). "Stress, Intrusive Imagery, and Chronic Distress," Health Psychology, Vol. 6, pp. 653-675.
12. Bekker HL, Legare F, Stacey D, O'Connor A, Lemyre L. Is anxiety an appropriate measure of decision aid effectiveness: a systematic review? Patient Education and Counseling. 2003; 50: 255-262
13. Diagnosis of Stress. Cathedral Hill Obesity Clinic, San Francisco, CA 94103, USA. https://www.ncbi.nlm.nih.gov/pubmed/12040539
14. Mathias Benedek, Christian Kaernbach. A continuous measure of phasic electrodermal activity. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2892750/
15. Rosan Luijcks, Hermie J. Hermens, Lonneke Bodar, Catherine J. Vossen, Jim van. Os, Richel Lousberg. Experimentally Induced Stress Validated by EMG Activity. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3988146/
16. Vinkers, Penning R, Hellhammer J, Verster JC, Klaessens JH, Olivier B, Kalkman CJ. The effect of stress on core and peripheral body temperature in humans. https://www.ncbi.nlm.nih.gov/pubmed/23790072
17. Adamo, Shelley A. The Effects of Stress Hormones on Immune Function May be Vital for the Adaptive Reconfiguration of the Immune System During Fight-or-Flight Behavior. https://doi.org/10.1093/icb/icu005
18. Zadra JR, Clore GL. Emotion and perception: the role of affective information. Wiley Interdiscip Rev Cogn Sci. 2011;2(6):676-685. doi: 10.1002/wcs.147
19. Michael L. Ray and Rajeev Batra (1983) ,"Emotion and Persuasion in Advertising: What We Do and Don't Know About Affect", in NA - Advances in Consumer Research Volume 10, eds. Richard P. Bagozzi and Alice M. Tybout, Ann Abor, MI : Association for Consumer Research, Pages: 543-548.