Anxiety detection using wearable monitoring

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ABSTRACT
Social Anxiety Disorder (SAD) might be confused with shyness. However, experiencing anxiety can have profound short and long-term implications. During an anxiety span, the subject suffers from blushing, sweating or trembling. Social activities are harder to accomplish and the subject might tend to avoid them. Although there are tested methods to treat SAD such as Exposure Therapy (ET) and Pharmacotherapy, patients do not treat themselves or suspend treatment due economic, time or space barriers. Wearable computing technologies can be used to constantyly monitor user context offering the possibility to detect anxiety spans. In this work we used Google Glass and the Zephyr HxM Bluetooth band to monitor Spontaneous Blink Rate (SBR) and Heart Rate (HR) respectively. We conducted an experiment that involved 8 subjects in two groups: Mild SAD and No SAD. The experiment consisted on an induced anxiety situation where each participant gave a 10 minutes speech in front of 2 professors. We found higher average heart rates after induced anxiety spans on the mild SAD group. However, we found no evidence of increased SBR as an anxiety indicator. These results indicate that wearable devices can be used to detect anxiety.

Categories and Subject Descriptors
J.4 [**Human-centered computing**]: Ubiquitous and mobile computing

General Terms
Experimentation, Measurement

Keywords
Google Glass, Wearable Monitoring, Anxiety, Social Anxiety Disorder, Social Phobia, Anxiety Detection

1. INTRODUCTION
It is widely known that some people are shy when facing an uncomfortable event, mostly because of their personality or other social factors. When this person faces this uncomfortable span, he or she could experience anxiety, which is a normal reaction in order to achieve a goal. However, when experimenting a higher level of anxiety that impedes him to carry a normal life, it is said that he suffers from an anxiety disorder [15].

The Social Anxiety Disorder (SAD) or Social Phobia (SP) is categorized as Social Anxiety and it has relation with Autism Spectrum Disorders (ASD) [12] and Obsessive Compulsive Disorder (OCD) [13]. SAD is classified as a phobia disorder in DSM-IV (Diagnostic and Statistical Manual of Mental Disorders) and in ICD-10 (International Classification of Diseases 10) [6]. Social anxiety is the most confronted clinical condition, occurring in 18% of the population in USA [14]. It tends to appear in late childhood/puberty and prevails in the rest of the life of a 5-12% of the USA population [6].

People who experience social phobia usually find themself inside difficult and awkward situations. Social activities like family or work meetigs, parties, talking with professors, asking for indications or facing an authority can turn into very stressing situations. Typically, the patient tries to evade them, therefore creating a vicious circle, where the person misses the opportunity to gain social skills to improve his quality of life.

The most common behavior in patients with SAD are evading eye contact when talking [10], being timid when talking to unknown people, remain quiet inside a social group, and avoiding unfamiliar social situations [13]. The person could experience physiological manifestations, such as blushing, sweating or trembling [6]. In their affective profile, patients show a peculiarity that distinguishes SAD from among other social problems: negative thoughts increase while positive thoughts diminish [4], hence getting a distorted vision of themselves. This misleading vision makes hard to participate in social activities because they think they lack the skills to perform appropriately.

There are psychological models as proposed by Clark, Wells and Rappee, Heimberg, that suggest individuals with SAD focus their attention to themselves and engages on the monitoring of their own sensations when foreseeing or entering a social anxiety situation [8]. The most effective ways to treat patients with SAD are: Cognitive Behavior Therapy (CBT) and Pharmacotherapy [3]. CBT is usually adequate for most

MexIHC '14 , November 03 - 05 2014, Oaxaca, Mexico, Mexico
Copyright 2014 ACM 978-1-4503-3285-9/14/11$15.00
http://dx.doi.org/10.1145/2676690.2676694

people. In spite of this, economic, uncertainty of where to seek help and fear to negative evaluation [11], are barriers that impede patients to adhere to therapies and therefore prolong their recovery.

The ability of wearable computing (small computers that can be worn as clothes) to record images, video, audio and constantly monitor the user context have high potential for detecting anxiety spans and support therapy applications, specially for exposure based interventions like CBT. Patients can record their achievements or failures to exposures and revise later with or without a therapist [5]. In addition, the penetration of these devices, and considering that users tend to carry these devices most of the time looks like an attractive way for patients with SAD to break down barriers that prevent their recovery.

The aim of this work is to detect anxiety spans by monitoring HR and SBR by employing wearable computing devices and an architecture deployed in a semi-controlled experiment. This work is divided as follows: in section one we present a brief introduction about the problem; in the second, we compare the previous work and our contribution; then we present a detailed description of the architecture deployed and the algorithm we used to process the data. The next section includesthe results of the experiment; consequently, we discuss our results, continuing mention the limitations of this work, and finally we show our conclussions and future work.

2. PREVIOUS WORK

Several approaches have been proposed in the literature to detect or treat anxiety trough technology. Some of these approaches make use of wearable devices. Table 1 summarizes the previous work in terms of wearable solutions.

One of the simplest ways is treating anxiety is with the use of videoconference calls. Erica K. Yuen studied the feasibility, acceptance, and effectiveness at the beginning of interventions using the video conference platform Skype to treat adults with Generalized Anxiety Disorder [2]. Her intervention consisted on treating patients in their home, office, including one from inside a car in a parking lot. Results show that this modality of treatment is acceptable and feasibile from the patient's perspective as well as for the therapist. Thus proving that anxiety can be treated at a distance.

Patients with SAD tend to not be psychologically treated because of economic barriers [11], uncertainty of where to ask for help and fear to negative evaluation. A study explored the possibility of using virtual reality from the online community "Second Life" as a platform to perform sessions, obtaining as a result that "most of the patients and therapist considered this modality of treatment as acceptable and feasible, besides being easy to learn even though technical issues emerged" [11]. Her results show that treatment in Second Life using Exposure Therapy based on acceptance was highly effective to reduce symptoms of social anxiety. It also helped to reduce evasion and disability, alleviating depression and increasing their quality of life.

In traditional psychology, it is recommended to make interpersonal sessions with the patient during short time spans.

Table 1: Comparison of some Social Anxiety Disorder related studies

Study	Wearable Device?	Collected Data	Aim of the study
FaceIt [5]	YES	Heart Rate, audio, video, geographic position	Record anxiety spans to use them later in therapy.
Remote Therapy [2]	NO	Interviews, self report, questionnaires	Use smartphones to apply therapies.
Inner self comparison [8]	YES	Skin conductivity, heart rate	Compare inner self percepction to outer self perception on people with social anxiety.
Clasp [12]	NO	Hand pressure	Design a device to detect anxiety spans.
VRET [15]	YES	Heart rate, interviews	Use Virtual reality as a way to apply exposure therapy.
Audio Cancelation [13]	YES	Sound	Design a device to dimish anxiety while talking on persons with autism.
Social Phobia Therapy through smartphone [3]	NO	Interview results	Use smartphones to apply therapy.

Although these sessions work, there are some limitations that impede recovery of patient like economic barriers, time, or the fear to ask for help. Jesper Dagöö mentions: "smartphones have the potential to make psychological and health interventions more accessible, efficient and interactive for patients" [3]. In his study, Jesper supported therapies for patients with social phobia resulting in "delivered treatment via smartphone could work well when technical problems obstructed this experiment are solved", and it "is probable that clients prefer the option to choose the platform to be used".

A unique characteristic that makes Social Anxiety Disorder interesting is the fact that patients tend to monitor themselves when foreseeing or entering an anxiety span. This was studied by Désirée D. Deiters [8] where two groups of people with low and high social anxiety disorder were asked to give a speech while wearing a glove that monitored pulse in their index finger, giving the illusion to the user that he received feedback of his heart rate by a bone conducting device. Two electrodes measured the conductive capacity of his skin. The results show that "the group with high anxiety reacted significantly faster to internal impulses during the anticipation and on the speech"[8]. This provided evidence that the use of wearable computing could help to detect social anxiety.

A very vulnerable sector is people diagnosed with autism. Social anxiety has been often related with autism disorder spectrum [13] so the design of solutions are usually not conventional. Xi Wang says: "because of hypersensitivity to sound, patients with disorders in autism spectrum can feel frustrated and even deeply terrified when talking to different people at the same time" [1]. His prototype, a pair of glasses with two microphones and headphones with external noise cancellation, allows the detection of multiple sources of speakers and diminishes one voice selected by the user. Even though it hasn't been evaluated with autism patients, it offers a preliminary approach of how wearable devices can help quality of life on patients with disorders.

There are also several techniques to treat Social Anxiety Disorder. One of them is Exposure Therapy, where a patient is confronted with anxiety situations in a "controlled" manner. However, there are some limitations like the partial control of situation, costs and required time. In the study "Virtual Reality and mobile phones in the treatment of generalized anxiety disorders: a phase-2 clinical trial", is shown the use of Virtual Reality Exposure Therapy (VRET) is "completely controlled: quality, intensity and frequency of exposure is chosen by the therapist, and it could be stopped in any moment if patient cannot tolerate it" [15]. During the study, the participants were induced to anxiety while presenting different scenarios wearing augmented reality glasses. Their heart rate was monitored during the session with a Bluetooth wireless sensor. In one of the scenarios, the quantity of fire coming from a fireplace was controlled with the user heart rate. The results indicate that biofeedback reduced anxiety registered on the questionnaires. Also, they show that the use of mobile devices can help people therapies with social phobia, since they can be used at home without the help of a therapist, or rather holding it with themselves and use it after an anxiety span, favoring the attachment to the therapy.

The use of virtual agents has been tested for social anxiety treatment in environments where a patient must learn to develop social skills. These agents work as virtual beings that help in user training inside situations like interviews [14,9]. Generally, these tools make use of physical language features like eye contact evasion, movement of hands and arms, constant balancing, shaking of head and agitation of arms and hands [14]. Computer-aided vision plays an important role in achieving this goal because it can process data in a similar fashion as humans do and allows immediate feedback, however, it can be more difficult to implement in wearable computing devices due to setup and processing limitations.

A qualitative approach could be a good option to work with exploratory solutions. "Clasp" is a "novel anxiety administrator" [12] for adults diagnosed with autism with high functionality, that involves a wireless device that user squeeze with his hand (like a stress ball) and transmits the data to a smartphone. When detecting 4 strong squeezes, the application registers the geographic location and sends it by SMS to a friend, or opens a URL to calm the user with a pre-configured video. In their findings they mention the fact that touching serves as a remedy of anxiety or stress in patients with a disorder in autism spectrum.

FaceIt [5] is a tool that allows detection, storing and remembering situations where the user shows anxiety using the base of Cognitive Behavior Therapy. A Memoto-like device worn around the neck detects through heart rate episodes of anxiety and stores only these moments with video, audio and location. Subsequently, the data is transferred through the Internet to a special server and a web page allows the patient to store their anxiety spans and revive situations in a controlled manner. The fact is people with SAD tend to solidify these episodes as "bad moments", by revisiting these moments, the software allows them to analyze how really the situations were. This offers more tools to their recovery. The study shows that "mobile devices are already part of our everyday life. Research also demonstrates that mobile applications have the ability to increase auto consciousness and reduce stress levels". They also show that "for these reasons, we believe that this approach has the potential of assist in the treatment of cognitive behavior of people with Social Anxiety".

This review of previous work shows us that there has been some work around the treatmend and detection of SAD. However, this research has not focused on detecting anxiety, this is a topic that is vaguely mentioned. Also, in the cases where wearable devices were actually used, the hardware is a custom solution.

The intention of this work is to provide an exploratory way to detect anxiety spans using off the shelf technology.

3. METHOD

First, we applied a printed English version of the Social Phobia Inventory (SPIN, 21 Items) to 10 graduate students (2 woman and 8 men). Even tough all were native Spanish speakers, they had at least intermediate experience in the language and translation support was provided. The participants were then classified in two different groups according to the SPIN scale: No SAD and MILD SAD. No partici-

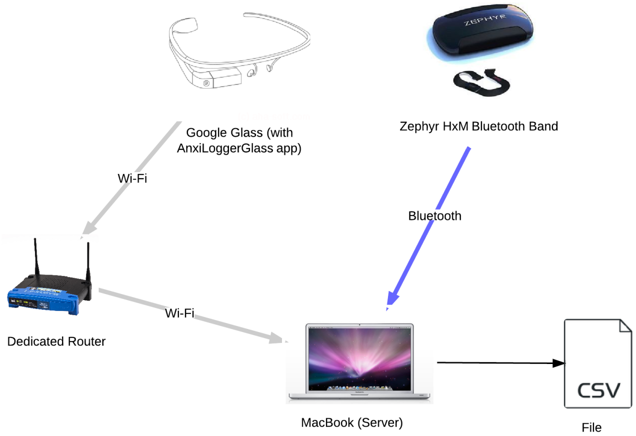

Figure 1: Data gathering architecture.

pant had a score high enough to be qualified over MILD SAD. Table 2 summarizes the results for all the 10 subjects. The test scale is as is follows: <20 None, 21-30 Mild, 31-40 Moderate, 41-50 Severe, >51 Very Severe.

Table 2: SPIN test results

Subject	SPIN result	Classified group
S1	14	NO SAD
S2	6	NO SAD
S3	25	MILD SAD
S4	17	NO SAD
S5	19	NO SAD
S6	25	MILD SAD
S7	23	MILD SAD
S8	21	MILD SAD
S9	3	NO SAD
S10	6	NO SAD

3.1 Architecture

For the experiment we employed three devices to monitor Heart Rate (HR) and Spontaneous Blink Rate (SBR) on subjects: a MacBook 2008, a Bluetooth Zephyr HxM band and a Google Glass with a custom application developed to transfer the data to the server. The setup involved a dedicated router to reduce data transfer delays and other common issues found in scholar networks so we could prevent data loses while transferring between the application and the server. Figure 1 shows a general view of the architecture used.

3.2 Server Side Programming

On the server side, we developed an application coded in the Python language to provide us basic functionality for storing the data provided by the wearable devices used in the experiment. We used Flask, a micro framework to transport data over HTTP. Our custom Google Glass app used this server. We also supported the communication from the Zephyr band over Bluetooth using the MacBook's built-in antenna. All data was stored into two separated files using Comma Separated Values (CSV) files for later processing and analysis. For each value we also annotated the time it was received so we could merge data from different sources later in the analysis.

3.3 Heart Rate Monitoring

The data coming from the Zephyr HxM band was directly stored on a file using a custom python console application called "anxilogger.py". We used an open source library to use the custom protocol (https://github.com/jpaalasm/zephyr-bt) this band uses and added specific functions related to this research. The device must be paired before using the application. There are three different modes: "no log" and "sample" and "anxiety induction". In no log mode, the application only shows the current hearth rate of the subject. Sample mode runs for 5 minutes saving the data in disk and then exits. Anxiety induction mode runs for an undefined time until the users asks to exit. These different modes facilitated the data gathering during the tests.

3.4 Google Glass Application

We developed a custom Google Glass application to gather data from the IR sensor. We used part of the GlassLogger application (https://github.com/shoya140/GlassLogger). There was not any prompt for the user since we only wanted to monitor the subject. The application consists in three parts: IR data gathering, IR data processing and HTTP communication. In the IR data gathering, the application reads directly the current value from a system file.

Since the IR sensor measures the distance from the device to the eye of the user, the application processes the data and calculates when the user blinked. Since the file where the current data sensor is stored in a system file, the device must be first "rooted" to use this application. In addition, the correct permissions must be assigned each time the device boots trough the Android Debug Bridge (ADB). The frequency of the reading is each time the sensor gives a value that is around 18 times per second.

3.5 Algorithm

The algorithm used was codded in Java, based on the approach proposed in [7], with minor modifications to suite our needs. We tracked the sensor readings to detect when the data gets a peak value to identify the blink event. For this, we took 9 readings of the data to check whether a blink event has occurred. By taking the average of middle values (points 4,5,6) and comparing it with a threshold (from 3.0 to 7.0) we could detect peaks in the readings. When a peak was detected, it was marked as a blink. Since there were distance changes with movements of the user, and false blink events were to high, we used the extra movement threshold. This same algorithm was coded into a python to calculate the number of blinks in post processing. Figure 2 shows this tool while comparing with grounded truth in laboratory conditions. The dots marked on the graph are the moments when a peak is detected. Whether a blink event was registered or not, each sensor reading was sent to the server for later processing using the HTTP Method. This algorithm

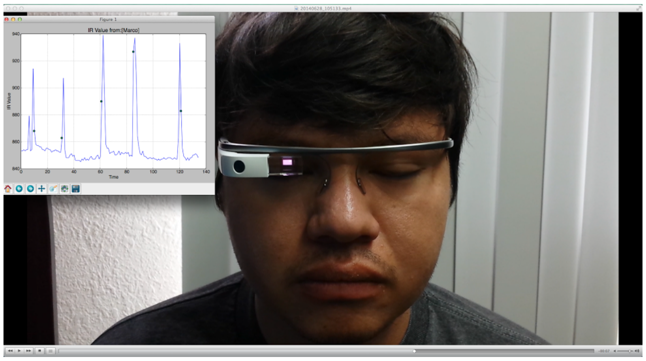

Figure 2: SBR detection using Google Glass.

made some estimation errors when the head moves and introduces noisy data in sensor readings. We found this while moving around the head.

3.6 Testing

We conducted preliminary tests to check if the application performed well on a desirable scenario. We used Google Glass while sitting and stating still to prevent introducing noise to the data. The readings from the sensor were correctly processed and the application played a sound each time a blink was detected by the algorithm. While compared to actual events, we found that false blink events were registered when we slightly moved the head. Although we adapted the algorithm to function as needed, we found that the application detected many false positives blinks. For this reason, we manually registred the blinking data from recorded videos.

3.7 Experiment Scenario

We formulated the following hypothesis for the intervention:

H1. -The SBR of the subject with SAD will rise after an "aggressive" question
H2. -The HR of the subject with SAD will rise after an "aggressive" question.

The intervention was conducted in two consecutive days, with 4 participants each day. A notification email was sent one day before to the students with the time, place and materials they needed to participate. We explicitly asked them not to drink coffee, soda or high sugar candies at least 8 hours before the experiment. They were also asked to bring a laptop and an optional highlighter.

We used two rooms to conduct the experiment, one a regular classroom and an auditory, both from the Computer Science Department at CICESE. The rooms were next to each other and kept at comfortable temperature of 24 degrees and 50% of relative humidity. We offered a bottle of water and a sugarless oat snack to both the subjects and the public. Subjects were not allowed to consume the snacks or water during the measures.

The experiment consisted on two tasks. In the first task, the subjects arrived to the classroom with 15 minutes of difference each. They were asked to choose a desk to sit and start their laptops and a snack was offered. 15 minutes after the subject arrived he was asked to wear the Google Glass and Zephyr Band. As the band needs to be worn under the clothes at the torso height, all females and 2 males used a bathroom nearby to place it.

In front of this chair a desk with a Macbook running the anxilogger tool was installed. A dedicated Wi-Fi router with the dd-wrt firmware was deployed at the site to connect the Google Glass with the laptop and no Internet connection was provided. A Samsung Galaxy S4 with stock firmware was attached with a special support to the desk and used as a video camera only. No Internet connection was provided to the smartphone either.

The subject was asked to relax and stay as still and idle as possible during 5 minutes. His hearth rate (HR) and the Spontaneous Blinking Rates (SBR) were then saved in CSV format in the computer. We kept the room as quiet as possible since at least one more subject was inside while measuring. After the measuring, the subject was asked to remove the devices from his body and sat back on his desk. A scientific article from the ACM CHI 2013 or 2014 conferences was provided in both paper and electronic media. He was asked to study it and create a short presentation of maximum 4 slides with no text but the title for a period of 30 minutes. After the presentation was created, he was asked to send it in PDF format by Mail.

In the Second task, the participant was asked to give a speech in front of two professors of the Computer Science Department of CICESE in an auditory sitting in the first row. The public was provided with a copy of the presented articles, a bottle of water and a snack. The auditory was equipped with a projector, another Samsung Galaxy S4 used as a video camera, a laser pointer and two laptops: one to control the presentation and another one to monitor the subject. The subject stood in a mark on the floor so the camera could record it without the subject going off scene. During the speech, the subject had a maximum of 10 minutes to present the article and the professors were able to interrupt with questions at any time. The speech and the questions were made in Spanish.

3.8 Data Processing

Data was saved in a hard disk in four different types of files: One for HR, one for SBR from Google Glass, a third one for a manually codified blinking from the videos and a last one for the transcripts of the questions made by the public. All of them used a CSV format. A set of tools was specially developed to plot, calculate, anonymize and export the generated data. All the names of the subjects were anonymized using this set of tools. Figure 3 shows an example of the plotted HR and SBR data of a subject during the two tasks.

Since the blink detection was not reliable enough, we coded the SBR within the question transcripts between 2 persons. All data of each question was then labeled in one of the three possible classifications: "NEUTRAL", "LIGHT", or "AGGRESSIVE". A neutral question was an interruption that the speaker does not have to answer. Light ones were the questions where the speaker must answer but does not

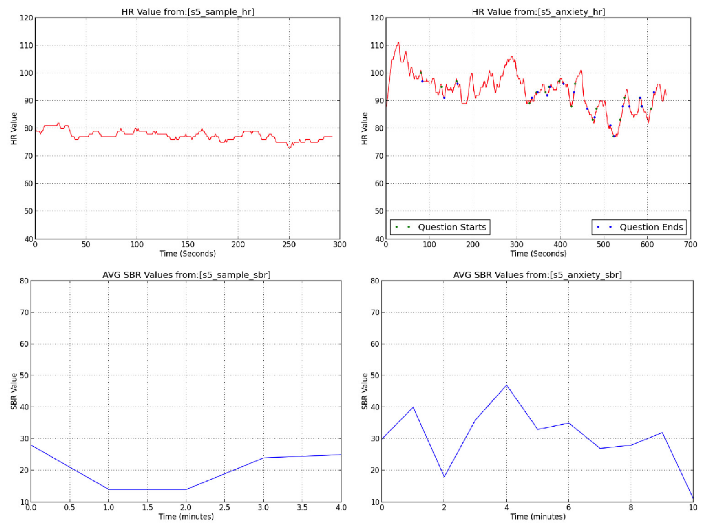

Figure 3: HR and SBR values of from first task (left) and second task (right).

demand considerable mental effort, while the aggressive ones were the ones where the speaker was questioned and required a significant mental effort to respond. Table 3 exemplifies the classified questions.

Table 3: Classified questions from speech test

Subject	"Question transcript"	Classification
S5	*"Conclusions?"*	AGGRESIVE
S1	*"They tested an hypothesis or something like that?"*	AGGRESIVE
S7	*"What where your conclusions?"*	AGGRESIVE
S8	*"They evaluated them and were given the same survey?"*	LIGHT
S8	*"But what were they measuring?"*	LIGHT
S1	*"What was the red studd? I do not understand."*	LIGHT
S2	*"Ah."*	NEUTRAL
S3	*"With his own Facebook account."*	NEUTRAL
S2	*"... it is simple."*	NEUTRAL

A final integrative tool ("calculatequestionsdiff.py") was developed to generate a table with the average values of the 15 minutes before and after each question of HR and SBR (AVG_HR_BFR_QUESTION, AVG_HR_AFR_QUESTION, AVG_SBR_BFR_QUESTION, AVG_SBR_AFR_QUESTION) within a transcript of the question, subject number and group. The data was then exported to LibreOffice Calc to complete the statistical analysis.

4. RESULTS

In order to test our hypothesis, we conducted a one-tailed T-test over the average values of HR and SBR data before and after the questions. Table 4 summarizes the tests for HR while Table 5 summarizes the tests for SBR. To prove H1 we conducted the "TTEST_AGGR_SBR_MILD_SAD" test. A sample size of n=26 was used. That is, 26 different aggressive questions for all the 8 participants. The result showed no statistical differences ($p > 0.5$). Therefore the hypothesis 1 is rejected. This might be explained because when a person is concentrated, his/her SBR decreases. With that said, a different experiment setup where the person does not requires to be highly concentrated (such an informal meeting) should be used to test this hypothesis.

For the second hypothesis (H2) we conducted the "TTEST_AGGR_HR_MILD_SAD". A sample size of n=26 was also used. Although there was a statistical difference between the values ($p=0.0097280458$), we also found a negative standard deviation between the values (DIFF =-0.991265687). Therefore, the hypothesis 2 is also rejected. The reason to this result, might be explained with an inmediate relaxation of the person.

In addition, we conducted other tests, to see if there was any other interesting behavior. We found out that there was a significant difference in HR values while testing subjects of the SAD group in the LIGHT and AGGRESSIVE questions ($p<0.05$ in both cases with n=33 and n=26 respectively) while subjects with no SAD showed no statistical difference ($p >0.05$, n=33, n=26).

5. DISCUSSION

Although we could not prove our hypothesis, we found interesting behaviors in the data. It seems that persons with

Table 4: HR T-Test results.

TEST	RESULT	OBSERVATION
TTEST AGGR HR MILD SAD	*0.0097280458*	SIGNIFFICANT DIFFERENCE
TTEST AGGR HR NO SAD	*0.0657962425*	NO SIGNIFFICANT DIFFERENCE
TTEST LIGHT HR MILD SAD	*0.0209022427*	SIGNIFFICANT DIFFERENCE
TTEST LIGHT HR NO SAD	*0.178507039*	NO SIGNIFFICANT DIFFERENCE
TTEST NEUTRAL HR MILD SAD	*0.3457010612*	NO SIGNIFFICANT DIFFERENCE
TTEST NEUTRAL HR NO SAD	*0.0224635532*	SIGNIFFICANT DIFFERENCE

SAD show higher HR rates after a period of anxiety). These findings suggest a way to detect anxiety spans trough HR using wearable monitoring in patients with SAD.

Further research should be done focusing in those spans formulating a new experiment with pre-formulated questions to characterize the quantified values of the patient.

The results obtained from SBR were not significant enough in this setup. However, a different setup could be made in order to clarify if SBR is a real indicator of anxiety.

6. LIMITATIONS

There were some limitations in this research. The available number of subjects (n=8) and the close difference in the SPIN score from the two groups limited the quantity of data to work with. A new experiment with people diagnosed with high social anxiety levels should be considered.

7. CONCLUSIONS AND FUTURE WORK

We conducted a experiment to induce, and infer anxiety, showed a custom set of tools to gather, process and plot anxiety related data through wearable devices.

According to the literature and findings from the experiment, anxiety detections trough wearable monitoring seems feasible and a promising, personal approach to support patients with Social Anxiety Disorders. However, further research must be done to define a robust mechanism for detecting anxiety as well as in the applications to approach to a real, usable solution. As a future work, we think a better sensor than the IR on Google Glass could be necessary for eye blinking detection. Also, more different scenarios such as simulated job interviews or simulated social reunions might perform better at inducing anxiety. Using a smartphone to store and process data on the go would be the way to make mobile anxiety detection. Finally, using smart watches could provide a better comfort and interaction.

Table 5: SBR T-Test results.

TEST	RESULT	OBSERVATION
TTEST AGGR SBR MILD SAD	*0.4483793268*	NO SIGNIFFICANT DIFFERENCE
TTEST AGGR SBR NO SAD	*0.1720290981*	NO SIGNIFFICANT DIFFERENCE
TTEST LIGHT SBR MILD SAD	*0.1722901409*	NO SIGNIFFICANT DIFFERENCE
TTEST LIGHT SBR NO SAD	*0.3344851061*	NO SIGNIFFICANT DIFFERENCE
TTEST NEUTRAL SBR MILD SAD	*0.263900606*	NO SIGNIFFICANT DIFFERENCE
TTEST NEUTRAL SBR NO SAD	*0.00077100934*	SIGNIFFICANT DIFFERENCE

8. ACKNOWLEDGMENTS

We thank Dr. Monica Tentori for providing the Google Glass device, her kindness and disposition to help us in our research.

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