TradeZen
Emotion-reactive Interface for Financial Traders

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ABSTRACT
We propose a wearable sensor that constantly monitors various physiological metrics to gauge emotions and stress, then broadcast emotion-events to devices and applications that would proactively tailor their behavior accordingly. Specifically, we attempt to build a wearable stress-sensor that broadcasts stress-events wirelessly to trading software, either portable or on the desktop, so that the software requests explicit rationale for trades seemingly executed under stress. Our contributions are: A) Identifying that trading and other stress-sensitive activities do not need to have a wearable interface, but only the subconscious, first-person act of sensing moments of stress requires wearability, and B) Proposing that interfaces for stress-sensitive activities should pro-actively tailor itself to the stress level of its users, and C) Devising a scheme for a wearable stress sensor to update stress-sensitive applications wirelessly. We construct a low-fidelity prototype arm-band with Galvanic Skin Response sensors, and a bluetooth interface that broadcasts stress-events to an application on an Android phone. The application is a prisoner's dilemma game, instead of the proposed trading software, to facilitate repeatable experiments. We evaluate the device's effects on the consistency of decisions made under stress and conflicting evidence via observation of 12 subjects playing 3-player iterative PD games. The pay-off matrix changes to favor different strategies after random number of rounds, and we gauge the degree of consistency of the players' move patterns. Our results suggested that the subjects who wore the device and received stress warnings were more consistent in their moves, if perhaps not optimal. However, there were not enough subjects to produce conclusive results. We also found during prototype building that melody and rhythm shifts in music produces very clear GSR responses, which could suggest other applications for wireless emotion event broadcasts.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces---Input Devices and Strategies, Interaction Styles, Theory and methods; H.1.2 [Models and Principles]: User/Machine Systems---Human Factors.

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General Terms
Measurement, Design, Human Factors.

Keywords
Affective Computing, Galvanic Skin Response, Finance, Trading, Investment, Banking, Fund Management, Wearable Computing, Ubiquitous Computing, Stress Measurement, Emotion-reactive, Proactive Computing, TradeZen.

1.INTRODUCTION
Fund management (trading and investing) is an activity highly influenced by stress. Behavioral Finance Theory suggests that human are neither rational nor consistent (CFA, 2010). As the theory grew since the late 80's, many "anti-patterns" in the behaviors of bankers and investors had been developed. However, the most consistent theme is the fact that humans will make decision with total disregard for logic or prior planning in moments of extreme stress.

Placing trades on the financial market is a highly stressful, time-sensitive, and psychologically dependent activity. Very often, the best opportunities or the signs of danger only appear for a short period of time. As a result, investors sitting in a desk for hours or weeks waiting for this moment and can suffer from anxiety. This anxiety contributes to irrational behavior, such as excessive risk taking (before the right opportunity comes) and tolerance (waiting too long to react to danger signs).

There have been previous studies on monitoring the physiology of financial traders (Lo & Repin, 2001, 2002) and Poker players (Sung & Pentland, 2005). These studies confirmed with statistical significance that decisions with real financial stakes cause stress, which cause measurable difference in physiological metrics, such as skin conductance, heart rate, and body temperature... The involvement of real financial stakes in emotion monitoring experiments is critical in obtaining relevant results.

We also hypothesize that the stress in trading is partly caused by the intentionality of professional trading to produce results (profit) consistently, while risks and opportunities are time-sensitive in nature. In other words, not only the act of trading, but the act of waiting in anticipation of important events can cause stress (Miller et al, 2008). A more relaxed and varied environment than the office, such as walking around in a beautiful park, could help to reduce the stress associated with waiting and anticipation. The perfect trading platform should be able to facilitate moments where both the mind and the market present the best opportunity.

We propose TradeZen, a financial trading device that tailors its system image and allowable actions to the trader's stress level.

The device gauges the mood of the trader, and actively warns against obsessive or anxious behaviors. On the flip-side, TradeZen would also suggest background tasks to a fund manager, such as market research or portfolio planning, whenever the stress level appears very low.

TradeZen gauges the mood of the trader using two unrelated methods: A) It takes advantage of wearable sensors of physiological metrics that are stress indicators, receiving wireless updates of stress levels and abnormal events from these sensors; B) It uses well-documented and proven heuristics in Behavioral Finance to detect when the trader is acting irrationally. Enforcing Behavioral Finance mainly involves learning the trader's usual behavior, such as average purchase lot size, and requiring explicit rationale whenever a trade breaks the pattern.

2. BACKGROUND AND CONTRIBUTION

Our work is related to Wearable Computing. However, wearable computing applications have largely been applied in the areas of augmented reality (Starner et al, 1997) or in moving the PC-analogy from the desktop to the human body. There are many other works pursuing these directions of wearable computing, but they are unrelated to our work. Although we originally would like to have the trading software, and subsequently a computer, to be wearable in our concept, we decided that these activities do not gain any usability benefit by being wearable, as opposed to simply being on a portable device, such as a smart phone. Our work is more closely related to Affective Computing, as only the emotion-sensor is wearable.

Although there are highly-related works on Affective Computing, where the machine will adapt to the user's emotions (e.g. Picard, 1999), we have not found any application of wearable computing specifically for trading and other financially stressful situations. We also have not found any application where the only the sensor of emotions is wearable, and detached from the devices and software that are informed about the user's emotional state. Commercially, Panasonic (2007) and Philips' (Oct, 2009), have created prototypes that detect simple biometrics and displays a graphically-pleasing visualization on the users' mood, which can help traders. Body Media produces Sensewear (2006), a wearable sensor arm-band that tracks Motion (via an accelerometer), Steps, Galvanic Skin Response, Skin Temperature, and Heat Flux, and has found adoption in the medical field for patient monitoring. However, these products are passive displays of emotions that could very well be ignored in the heat of the moment.

The US military (Perala & Sterling, 2007) used Body Media's Sensewear to evaluate the effectiveness of Galvanic Skin Response as an ubiquitous, real-time measure of the stress level of soldiers in the field. The results of this study suggested that GSR is a viable and relatively reliable measure of stress, considering the ease of deployment and the low level of invasiveness. This result was one of the reasons for our use of GSR as the measure of stress.

The wearable interface that is perhaps most closely related to our work is the AutoSense Project (Kumar & Scott, et al. 2009) by the National Institute on Alcohol Abuse and Alcoholism. In this project, sensors for various physiological metrics, including GSR, communicates wirelessly with a mobile device for the purpose of monitoring and quantifying personal exposure to psychological stress and addictive substances in natural environments. However, the monitoring is passive in nature, whereas we propose to create applications that would receive wireless broadcasts of stress events, and react to them, to actively mitigate the risk of irrational decision making.

Our work is also highly related to ubiquitous computing. There have also been literature that suggests a combination of ubiquitous and wearable computing to overcome each other's shortcomings (Rhodes et al, 1999). We believe that the concept of wireless broadcasts of emotions and emotion-reactive applications will become truly powerful when the sensors become small and unobtrusive enough, and there are many applications that can receive and react to wireless emotion event broadcasts in order to tailor the system images that they present to the user in a streamlined fashion, integrating into human activities and augmenting the human creature's ability to deal with stress.

The TradeZen product, and the idea of emotion-reactive interfaces that we propose in this paper, also shares a close link to, and a step toward, the vision of Proactive Computing, first promoted by Intel Research (Tennenhouse, 2000). An aspect of Proactive Computing is the concept of applications that "anticipate our needs and act on our behalf." TradeZen anticipates moments where the user may not be in full control of his/her action, and pro-actively assists him/her in dealing with stress. Another aspect of Proactive Computing is the requirement for wireless interaction between the sensors and the applications, which was implemented in our product via bluetooth. In Tennenhouse's vision, the sensors will become ubiquitous in the environment, and supply information to applications. Our work subtly extends that vision, by proposing that the sensors could be on the human body as well.

Although we propose that TradeZen could also assist a trader in stress management via machine learning and identifying obsessive behavioral "anti-patterns" (which could very well be the ones documented in Behavioral Finance), we limit the scope of this paper, and our proof-of-concept prototype, to only the wearable sensor and wireless stress broadcast. Anticipation of user's need via machine learning is also another aspect of Proactive Computing, which we planned to implement, but chose not to, due to time constraints.

Our contributions to Human Computer Interaction, specifically to Wearable, Ubiquitous, and Proactive computing, are:

A) Identifying that trading and other stress-sensitive activities do not need to have a wearable interface, but only the subconscious, first-person act of sensing moments of stress benefits from wearability.

B) Proposing that interfaces for stress-sensitive activities should pro-actively tailor itself to the stress level of its users.

C) Devising a scheme for a wearable stress sensor to update stress-sensitive applications wirelessly.

3. CONCEPTUAL DESIGN

The mental model of a traditional computerized trading platform is simply a realization of the interactive model of computing. The trading software (the computer) is static and passive, with an input facility. The human user, the trader, interacts with the software by issuing commands in exacting details, and the software executes the command. Perhaps barring undisclosed trade secrets, even the most sophisticated trading software employed by top hedge funds still operates on this model. Even if the input facility can be as complicated as a script of trading strategies, instead of single or block trades, the principle is still "the human commands, and the computer jumps."

Figure 1. Traditional Trading Software Mental Model

This implies that the computer is a slave to the will of the human. However, as illustrated by various infamous incidents in the financial industry, such as the May 5, 2010 “Flash Crash”, and the Sept, 2008 “Fake Bankruptcy of United Airline” cases, the will of humans may not always serve their own best interest. On May 5, 2010, a simple routine risk-balancing trade by a conservative mutual fund was noticed by other traders as being abnormally large for that quiet day, and that triggered a sell-off within minutes that dwarfed the darkest days of the Financial Crisis in intensity and damage. It was later found that traders, including those who configured automated trading algorithms, sold-off en-masse in those few minutes for no clear rationale. Even though a large number of the trades on that day were reverted, the image damage to America’s financial industry was unquantifiable. Similarly, on Sept 8, 2008, a 5-year-old article on the bankruptcy of United Airline was re-circulated widely on the Internet, briefly becoming prominent on search engines, and triggered a one day sell-off of United Airline stocks that brought the company’s common stock from $10 to as low as $0.05, before smart traders realized that the date of the article was in 2003, and bought the shares back up.

It would seem unthinkable to a rational mind that thousands of Finance professionals did not see the date field of a news article at the same time. However, these incidents are not singular, isolated cases. Since the 1980’s, there had been a school-of-thoughts in Finance and Economics that the theories of Economics and Finance are actually fundamentally sound, but the people working in the industry are not consistently adhering to these well-thought-out and carefully tested principles, due to stress caused by greed and fear.

There are indeed many situations in life, beyond the specifics in the Finance field, where a person’s capability for rational decision making is compromised, such as when cognitively overloaded, competitively and financially stressed, or under the influence of substances and illness. In these periods, the interactive model of computing becomes less effective at serving the needs of us, human beings who can be inconsistent and irrational.

It is almost as if the software had an insufficient picture of what the human user was trying to input to it. Human, at any given moment, output not only their rational thoughts, but also their emotions. The emotions are often subconscious, but a part of their will nonetheless. A trading software that takes each command given to it at the surface level is like a function with two parameters, “logic” and “emotions”, that simply never uses the second parameter.

The mental model of TradeZen solves this problem. TradeZen still consists of an financial trading application that could run on multiple platforms, such as a desktop or a portable device. This application would still take commands from a user like traditional products would. These commands seem to represent what the user logically wants. However, since emotions took a part in forming those commands, they must also be an input into the working of this trading application. Emotions are often subconscious, so they have to be sensed. A wearable sensor on the trader autonomously and constantly measures various physiological metrics, interprets this data as shifts in stress levels, and informs the trading application. The trading application then counter-proposes to its users whether the command, or a variation of that, is what they actually want. In the case that the stress level seems to be low, the trading software would behave as if the “emotions” parameter is zero, and executes command as is.

Extending the mental model further, there are also many cases where the “logic” parameter is zero as well. For example, a trader is taking a stroll on the beach with his dog, watching the sun setting on the ocean. The TradeZen sensor would detect that his stress level is so far below even the normal baseline that perhaps he should attempt to read up on market news and think about strategies to rebalance his portfolio. The application in the trader’s smartphone, receiving constant updates from the sensor, would simulate the vibration and beep of a text message, and display a message to the trader:

“Master Bruce, it is a rare sight to see you so at peace. Perhaps you should consider rebalancing your portfolio.”

Figure 2. TradeZen Mental Model

4. ARCHITECTURAL DESIGN

HIGH LEVEL

We planned in our project proposal to leverage MIT's LiveNet platform to fulfill our requirements of connecting a smartphone interface and multiple human measurement sensors. Upon further research of the LiveNet platform , we realized that:

1. The technology is closed.
2. We can't find a trading API on the hardware platform.

However, we have found an alternative viable solution. We will leverage the Java-based Android phone, and link to the phone via bluetooth.

The sensors are implemented on an Arduino Uno board, with a Bluetooth Mate modem that acts as a wireless serial pipe to send signal from our Arduino-board-mounted sensors to the Android phone installed with Amarino. We developed our application using Amarino, linking via the LGPL license. Amarino is an open source (LGPL) library that allows Arduino to communicate effectively with the Android phone.

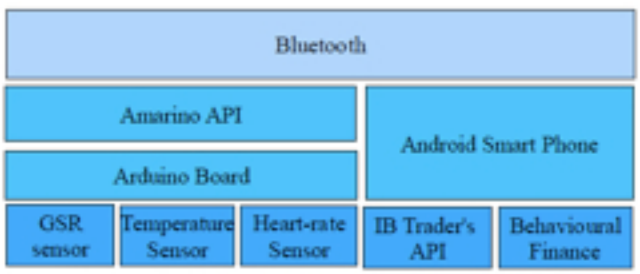

Figure 3. High-level Architecture

PROTOTYPE FORM FACTOR

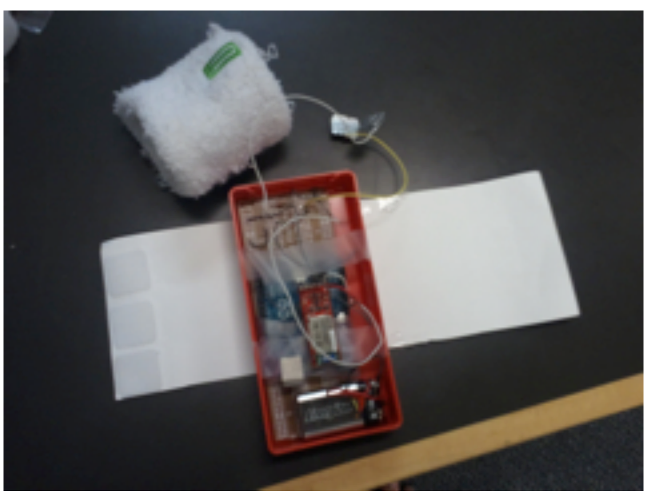

Figure 4. Form Factor, at rest. The prototype consists of a wide arm-band (for comfort and a secure grip) attached via velcro, the arduino board with the event recognition and broadcast logic embedded, a bluetooth modem, and the GSR sensor board and electrodes.

GSR SENSOR

We originally planned to implement a GSR sensor, a heart rate sensor, as well as a stress-ball that connects to a pressure sensor as three measures of stress. This would have allowed us to triangulate the data of the three methods and produce a reliable measurement of stress.

Due to time limit, we decided to only use GSR as our measure of stress, despite knowing that it is very difficult to implement a reliable GSR sensor and scheme for detecting stress via this data. The 2007 study by the US military, however, provides promising results suggesting that GSR is indeed a relatively reliable method for light-weight, non-invasive stress measurement in the field. We had finished wiring up the pressure sensor, but abandoned the idea last minute due to difficulty getting multiple streams of data to update the Android phone interface.

The GSR detection circuit is centered around two electrodes made out of aluminum material. The electrodes will be attached to the user's skin. The circuit uses a three hundred thousand ohm resistor in series with the two electrodes. The detection wire is connected from a point between the electrodes and the resistor into the Arduino input pin. The whole circuit is then connected to the five volt output and GND pins on the Arduino board.

The receiving voltage is sent out of the serial port of the board, via the Blue-tooth Mate modem, to the receiving Android - Amarino application. The readings are sent once every fifty milliseconds. When the android application receives the readings, it will collect it into a running average buffer. The total size of the buffer is about four seconds of data; when it is full, the application will average the total buffer size for smoothing purposes and send this value into our stress event recognition and broad cast logic embedded in the Arduino board.

For the event recognition module, we first take a baseline of the user's GSR when he/she is calm for 3 minutes. This is done before the experiment starts. Once it is taken, it is compared to the smoothed reading once every four seconds. If the difference is above or below a certain threshold, then we know that the user is not in a calm state and inform the user.

We tuned the threshold value and the optimal distance and location of the electrodes by conducting an informal evaluation on our team members, which we will also described in this paper.

5. EVALUATION CONSIDERATIONS

We considered carefully how the TradeZen model can be proven. We are ready, and able, to commit the time and effort into building a high-fidelity prototype of the TradeZen product itself, with complete integration with the market. However, we decided to take a more scientific approach, and thought about how we would conduct an evaluation of the effectiveness of the concept.

We start by formulating research questions on how TradeZen could make a difference to the fund management professional.

1. *Using a device that monitors and displays stress level and pro-actively interrupts the action of placing trades if the wearer is showing signs of stress, can a trader achieve better return than using a similar trading software without the mood-sensing and warning features, given access to the same information?*
2. *Does a trader achieve a more optimal portfolio if he/she receives suggestions from TradeZen to conduct portfolio*

rebalancing and market research in moments when the system determines that the trader is calm?

Answering either of these questions is difficult and may not be scientific. The involvement of the market, and real trading situations and data, require any experiment to be conducted on the time-frame of months and years, in order to show any consistent benefit to the bottom line. The financial stake involved in such a trial would make the study impractical, unless conducted within the scope of an enterprising investment institution or government body. More importantly, the path to "better return" and the definition of "optimal portfolio" are both ambiguous and ever changing in the real market. The market is just simply so complex, with so many stakeholders, that if it could be easily deconstructed in order to strategize against, it would have been a game, and this research would have been completely unnecessary.

First, we decided not to test TradeZen's ability to issue suggestions to trader during time of calmness so that he/she can turn to the task of trading when mentally ready. To answer that research question may make our experiment design too time-consuming, and potentially too complex to be reliably repeatable.

We then made the assumption that fund managers and commodity hedgers, users of TradeZen, already have their own systems and beliefs, and would only like to ensure that they and their employees would simply adhere to the strategy for each trade without being influenced by emotions in the heat of the moments. We then ask:

Does the awareness of stress and task blocking warnings that must be manually acknowledged at the point of decision making helps induce more consistent, systematic behavior in the face of time constraint and evidence discouraging the formation and adherence to decision-making systems.

We designed a controlled experiment that does not use a real trading situation and market data to answer this research question. Our hypothesis is:

In a strategically-complex and stressful activity, if a person is made aware of his/her stress level and required to explicitly confirm his/her decision before committing, he/she will be commit fewer actions that deviate from his/her strategy, even when facing time constraint and a conflicting informations.

To ensure scientific validity, we determined that our evaluation strategy must fulfill these requirements:

- Must measure *consistency* of decisions
- Must be a stressful activity
- Must be a strategically complex activity
- Must be a controlled environment, where the "consistency" of subjects' decisions can be quantitatively measured.

6. LOW-FIDELITY PROTOTYPE

We built a Low-Fi prototype to support our experiment design. We considered the prototype Low-Fi because we replaced the trading application in our TradeZen concept with a fast-paced, noisy, and iterative prisoner's dilemma game with procedurally generated pay-off matrices that favor different strategies after random number of rounds.

The prototype, however, still contains all the elements in the mental model of a TradeZen system:

- Wearable sensor: an armband with Galvanic Skin Response electrodes.
- Stress event detection: the logic for gathering a baseline level and identifying abnormal events is embedded onto the armband hardware.
- Wireless broadcast: via a bluetooth serial-port-analog.
- Application that receives wireless stress events and reacts to them: on an Android phone, to demonstrate that the wireless stress event update benefits applications of many types of form factor, on the desktop, portable, etc.

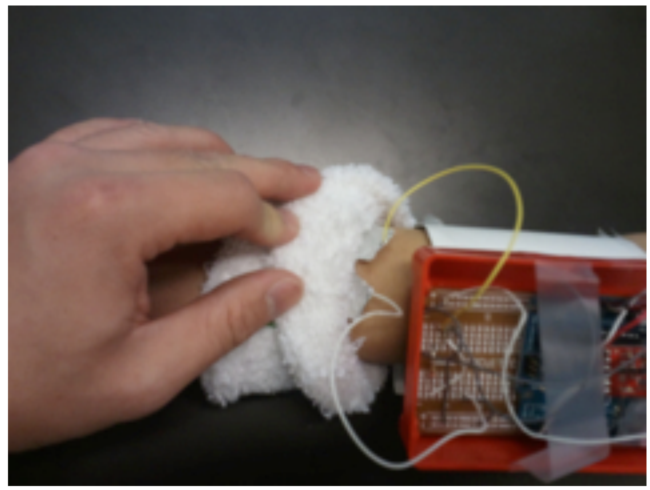

Figure 5. Low-Fi prototype, armband, GSR electrodes not attached under the armband, but pressed into the skin by another elastic armband, so that the location of the sensor and the distance between the two sensors can be tuned to find the scheme the yields clear raw data.

Figure 6. Low-Fi prototype, as worn during the experiment. The prototype weighs about 100g battery-included, the same as most cellphones, and this weight is distributed over a wide armband in order to increase comfort and not to create a new source of stress.

Figure 7. Android phone with experiment application (prisoner's dilemma game). Top Text Box: pay-off matrix and stress warning, Top Button: Defect, Middle Button: Cooperate, Bottom Button: Create Baseline.

The stress warning will appear in the top text box when the user chooses Defect or Cooperate each round, forcing the user to choose again. The phone will also vibrate when there is a stress event. A three minute sample of the raw data will be used as a baseline to indicate normal stress level.

7. EVALUATION METHODOLOGY

We conducted an Observation of subjects wearing our armband prototype and using applications that receive stress events from the arm band. The control group uses the same game format and interface as the test group, but without having the arm-band.

We decided not to use any think-aloud method because that may make the subject conscious of the task and skew the results.

Our formal evaluation was conducted with a Prisoner's Dilemma game task. However, while building the prototype, our team also conducted an informal evaluation on the team members to tune the placement and distance of the sensor electrodes. For that evaluation, we let our team members listen to randomized playlist while wearing the device.

PRISONER'S DILEMMA
Subjects:

9 subjects with similar backgrounds, education, Undergraduate Degree or some Graduate Studies, and age group (20-25).

Trials:

The subject plays competitive 3-player iterative Prisoners Dilemma games. The pay-off matrix is procedurally tweaked after certain random number of rounds, so that the optimal strategy changes. Even within each set of rounds, a small randomness factor is applied on to the pay-off matrix, so that even if statistically the pay-off matrix in each set of rounds would favor one specific strategy, the exact pay-off values never look the same.

Despite the procedurally generated nature of the pay-off matrix, either Defect or Cooperate will be chosen (randomly each set) as the statistically favorable move. 3 sets are played for each subject group, making the game last about 45 minutes.

The rounds are also very short, about 3 minutes each. This is to overload the subjects cognitively and force them to think on their feet, especially when the pay-off matrix changes.

After each round, the subject will be informed of his/her own score, but not the score of the two opponents or the moves that they made.

The observer stands beside the subject wearing the armband and playing the game on the Android phone, silently observing the stress graph and recording stress event warnings.

The game is mediated by a game master, who announces every events in the game, the start of round, end of round, time limit of each round, and the start and end of each set when the pay-off matrix will change. This announcement is done in a very flamboyant and fast, Loto-announcer-like fashion to enhance the atmosphere of competition, in an attempt to create stress.

To further confuse the players, the game master will routinely talk loudly about optimal strategies for playing iterative prisoner's dilemma game. All of these announcements are ultimately irrelevant to the actual optimal strategy, since the announcements are about 2-player games, and the pay-off matrix of our games are actually changing, and does not conform in anyway to the classical PD game.

MUSIC LISTENING

In the preliminary tuning tests of our device. Our team members took turns to wear the device, put on a headphone, and listen to a playlist that is being randomly modified in real time by the other team member.

The other team member also observe the GSR graph and the events identified to tune the voltage, location of sensor, and distance between sensor electrodes.

We found that the GSR value responded very reliably and quickly (in the order of 5 seconds) whenever there is an unexpected change in tempo, pitch, and volume of the music being played.

We also found out that GSR became much more effective when the electrodes are very close together, within 1 cm, and placed either on the underside of the wrists or on the palm of the hands.

8. RESULTS AND ANALYSIS

We found that the subjects using the device seem more consistent with their first-set strategy, regardless whether this strategy is still relevant in the subsequent rounds.

Strategy changes are easily identifiable by noticing who wins each set, and also by calculating the ratio of D and C for each set. The optimal strategy for each set is known procedurally, so the set results and the ratio of D and C are together reliable measure of a player's strategy.

Among the control group (without the arm band):

2/6 subjects changed strategy completely each round.

3/6 subjects changed strategy slightly each round.

1/6 subject keep the same strategy throughout.

Among the group with the arm-band:

2/3 subjects keep the same strategy throughout.

1/3 subject changed strategy slightly each round.

We do not consider out results conclusive, however, because:

- The number of subjects were not high enough. Requiring 3 subjects per trials, only 3 trials were actually carried out.
- The stress event threshold seemed to be too high. Even though the stress level is shown in the graph, only 1 out of 3 subjects was stressed enough to receive a notification. This means that the device's function may or may not actually affected the way the subject played. It is possible that the presence of the device itself altered the subject's behavior

That said, we routinely observed the GSR value approaching within 10% of our threshold at various points during the game for all three subjects wearing the arm-band.

9. DISCUSSION

We found that the device, whether directly or not, seemed to affect the consistency of decision making in our test subjects in stressful, time sensitive activity.

We learned that constructing wearable sensor with wireless update to various device (smartphone, laptop, PC's) are relatively difficult due to:

- Incompatible, none-standardized hardware and software.
- Creating form factor is time consuming, especially to make sure that the device is wearable, and the sensors are mounted securely.

However, our research into the technology of our device revealed that all of the elements in the TradeZen concept can be miniaturized, making the prospect of an always-on wearable sensor very viable.

The concept is applicable beyond Financial Trading. As sensors and devices become smaller and cheaper, and the wearing of sensors become more socially accepted, we could see that such a concept of proactive computing with wireless emotion updates and active tailoring of applications to users' emotion can be applied in:

- Situations where the user is under the influence of stress.
- Situations under time constraints.
- Cognitive overloading: driving, piloting, air traffic control

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