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Self-Aware Trader: A New Approach to Safer Trading

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Abstract: Traders are required to work in the financial market with highly complex information and to perform efficiently under high levels of psychological pressure. Multiple disciplines, from programs with artificial intelligence to complex mathematical functions, are used to help traders in their effort to maximize profits. However, an essential problem not yet considered in this rapidly evolving environment is that traders are not supported to adequately manage how stress influences their decisions. This paper takes into consideration the negative influences of stress on individuals and proposes a system designed to support traders by providing them with information that can reduce the likelihood of poor decision-making. The system has been designed considering both technical and physiological aspects to make information available in a suitable way. Biometric sensors are used to collect data associated with stress, a software platform then analyses this information and displays it to the trader. The resulting system is capable of making individual traders, as well as teams of traders, self-aware of their levels of stress. The system has been tested in real environments and the results provide evidence that self-aware traders benefit from the system by reducing risky decision-making.

Keywords: Decision making, sensors, stress, stress measurement, trader
Categories: B.4.m, C.3, H.1.2, H.4.3, H.5.3, I.2.1, J.3, J.4, J.7

1 Introduction

Trading in a financial market implies making transactions with shares and bonuses. Decision making during the trading process is a good example of the importance of risk management in real-time. Risks have a high impact in decision making because

they can undermine our capability to make safe decisions. This requires that traders are aware of all risks involved in their operations.

There are several available tools to assist traders in their daily work: real-time chart tools, analysis of the companies by economic experts and real-time news. Furthermore, research has been carried out on how to assist the work of traders on a daily basis. For example, Wolberg [Wolberg, 2000] uses kernel regression for modelling financial markets or Ang and Quek [Ang, 2006] investigate a method of forecasting stock price difference on artificially generated price series data using neuro-fuzzy systems and neural networks.

Although this external information and this research are positive and useful, trading inherently depends on good judgment exercised during real-time decision making in the financial market. Crucially, no information is available to the trader about a major risk source in the decision making process: an unrealistically biased state of mind.

Hence, it is in the trader's interest to know if he/she is under stress, so that poor decisions may be avoided when stress is a risk factor. It is currently possible to use the sensor technology available on the commercial market to measure a person's stress level in real-time and this information can be fed back to him/her. Here we merge knowledge on stress effects and sensor technology in order to establish a system to feed back the stress levels information in real-time to traders. This helps traders to avoid mistakes in the decision-making during the trading process.

The paper is organized as follows. Section 2 explains the relationship between stress, the decision making process and the biological response in the body to understand how stress influences trader. Section 3 explains the system used to feed back to the trader the stress level information, the Self-Aware Trader System. Section 4 describes the tests made with traders and the analysis and discussion of results. Section 5 summarises and concludes this paper by reviewing how the Self-Aware Trader System could improve traders' daily results.

2 Stress influence on traders' decision-making

Decision making in real-time is a key part of trading. The following paragraphs elaborate on the influence of the stress in trading decision-making and its influence in the human body (biometrical response).

According to [Steenbarger, 2003], the most common sources of trader stress are: excessive risk-taking, changing markets (volatility), unrealistic expectations, personality patterns and real life challenges. It is possible to see in [Steenbarger, 2006] how all of these have a high impact in the performance of the trader, independently of the source.

However, it is important to consider that there are some relevant studies supporting that the relation of the stress and performance is not always negative [Staal, 2004], in fact, stress sometimes works as a motivation factor [Park, 2011]. In this paper we will be referring to stress as a risk factor. Making bad decisions under stress can bring about catastrophic consequences, not only on the trader's finances or for the company that he/she works for, but also on his/her psychological health [Delgado, 2009].

2.1 Stress during trade

Traders continuously require good judgment in order to make good decisions in real-time. However, judgment and decision-making are altered under stress conditions. The problem is that when the trader is under stress, he/she is not necessarily aware of it, nor that his/her decision-making could be unsafe. In psychological terms this is named illusion of control. M.F. O'Creevy et al. [O'Creevy, 2010] gathered data from 107 traders in four organizations and showed a direct and inverse association between illusion of control and performance.

The most accepted theory is that when a person is under stress, he/she takes into consideration fewer alternatives when searching for a solution to a problem [Dougherty, 2003]. Gigerenzer and Selten [Gigerenzer, 2001] explain that when we have to make decisions, we use a toolbox of strategies and we apply the strategy with the most adaptive heuristic available. The best known heuristic is "Take the Best" (TTB). Broder [Broder, 2000, 2003] confirms how TTB strategy works with traders in an artificial stock market where subjects tended to expand their strategy when the cost of gathering the additional information was perceived as low.

Furthermore, decision making for traders is time-critical and this is also crucial in stress levels because the search for alternatives is truncated by the time limitation [Entin, 1990].

The traders' decisions are in cascade and there is evidence that individuals tend to rely on previous successful results of their decisions [Lehner, 1997]. For this reason, when a trader loses in one decision, this can negatively affect the next decision. Pixley [Pixley, 2002] argues that the intrinsic uncertainty associated with financial markets makes emotions such as confidence and trust an unavoidable element in corporative decision making.

From the research above and a more detailed review that can be found in [Martínez, 2012] it can be concluded that decision-making is degraded under stressful conditions. The problem is that when the trader is under stress, he/she may neither be aware of it nor of all of the effects it has on the decision making process (illusion of control) and he/she thinks that the decisions made have been correct. Studies [Oberlechner, 2005] associating stress and performance among traders (in experiments with three hundred and twenty-six financial traders) conclude that stress is possibly mitigated through self-knowledge and substantial latitude over trading style. Therefore, it is highly important to detect the moment in which the stress level becomes a risk factor and alert him/her, thus avoiding the illusion of control by self-awareness.

Stress levels can be deduced not only from the environment but also from biometric data taken from the trader. The next subsection will explain how physiological parameters reflect stress and how sensors can measure these parameters.

2.2 Stress related biometric measurement

The influence of stress has a high impact in the human body. Hormonal and other physiological changes are typical consequences of stress, and these are all interconnected.

Coates and Herbert [Coates, 2008] measured cortisol levels changes looking for the overconfident effects in London traders during risky market operations. They

found high variations on the cortisol levels, however, cortisol is usually measured by obtaining and analysing samples of saliva from the subject. Consequently, this parameter is not suitable for measuring the stress levels in real-time.

There have been some other attempts to use galvanic skin reaction but they are impractical for our target final users operating in the market, who require their hands free to use several devices to gather information [Viqueira, 2012]. In this sense, some solutions may be available in the future in the form of wearables, but this is still at embryonic stage and it is not clear when and if they will be available in the market or their level of effectiveness and affordability [Zhang, 2012].

Another approach to getting a stress measurement is given by the strong interdependence between stress and emotions [Braceland, 1953]. This branch of affective computing traditionally relies on the detection of emotional states by means of four approaches: facial [Rosenblum, 1996], speech [Nicholson, 2000], physiological features derived from emotions [Picard, 2001]; or a combination of these [De Silva, 2000]. These techniques are not entirely suitable for the trading process. For example, it is not possible for a trader to stare at a fixed point without moving or to speak on a continual basis. However, with the physiological measurements (skin temperature, heart rate, etc.) derived from emotions, [Lo, 2005] found that "…subjects whose emotional reaction to monetary gains and losses was more intense on both the positive and negative side exhibited significantly worse trading performance". The researchers conclude that emotions can be interpreted as a range of discrete values (sadness, happiness, fear, euphoria, etc.) and this can provide a starting point to translate emotions into stress level measurements.

Focusing on the physiological variables used to gather stress level, according to Cryer et al. [Cryer, 2003] when an individual experiences stressful emotions, whether conscious of them or not, the functionality of the brain is severely compromised by chaotic electrical and electromagnetic signals (cortical inhibition). The signals are measured by the beat-to-beat variation in the heart rate, known as Heart Rate Variability (HRV). The inconsistent and chaotic heart rate is a reflection of cortical inhibition. Work reported in [Barnea, 1995] describes the relationship between the changes in heart rate, blood pressure, skin temperature, and muscle tension in stressful moments. Skin conductance [Lang, 1993], the breathing rate [Adams, 1995], the brain waves [Ossebaard, 2000], and the pupil diameter [Yamanaka and Kawakami, 2009] are also related to stress. Lo and Repin [Lo, 2001] reported that physiological/biometric variables associated with the autonomic nervous system are highly correlated with market events even for highly experienced professional traders.

The studies mentioned above show us we can measure biometric variables as they change through sensors. The next section describes our architecture where we provide useful feedback on stress through a reliable and minimally intrusive system.

3 Self-aware trader system

The previous sections highlight the importance of traders' stress due to its impact in their decision making process and explained that stress can be measured. This section explains how we used those facts to develop a technological support to help traders reach safer decisions. Necessary biometric information is gathered from the traders to

feed them back their stress levels. They can then use this information during their trading process.

We start by explaining our technological platform. Also explained are the objectives the model tries to cover and the software developed. Finally we explain the two modes of operation, individual and group-mode, available in our system.

3.1 Sensor selection

According to the technical literature and the commercial products available on the market, the choice of sensors is heavily influenced by a) the trader's profile and b) the environment. Examples of a) are the work mode of the trader (whether he works for him/herself or for a company) and the type of trading (whether he is trading in shares, futures, commodities, risk profile, etc). An example of b) is the place where the trading process is carried out (sitting in a computer or live trading in Wall Street).

Most traders are sitting and working with a computer. This implies that wired communications are available, allowing processing of sensor data and data logging. Bearing in mind this scenario and our previous research about available sensors [Martínez, J., 2010, 2011, 2012], we applied the following selection criteria over some biometric sensors: data shown in real-time, stress measurement level available, available software for development, data logging, wearability, intrusive/non intrusive, accuracy, available sellers, price, autonomy and communication capabilities.

The sensor chosen considering these criteria was the HeartMarth's sensor with Emwave software [emwave, 2013] shown in Figure 1. This sensor allows measuring coherence/stress level in real-time. It is based on a USB Plethysmographic pulse sensor, which is attached to the ear lobe, with a sample rate of 360 samples/sec. The gain (increase needed for the amplitude of the signal) setting adjusts automatically via LED duty cycle (ratio between the pulse duration and the period of a rectangular waveform). The photo diode operating range is 30 - 140 beats/sec.

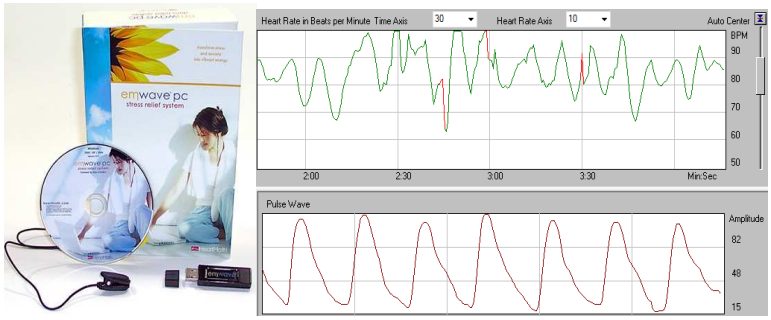

Figure 1: Emwave sensor and software (displaying heart rate and pulse wave)

3.2 Objectives and model principles

The sensor selected and the software included in it provides us with the biometric data gathered from the trader in real-time. The data is then managed by our system in order to fulfil the following objectives:

To increase traders' awareness of their own stress levels reducing the illusion of control alerting them in a way that can increase effectiveness

To extend the trader's awareness concept to a group-mode and use this information as a measure of the predominant state within the market in real-time (market feeling).

Psychological aspects must be considered along with technical and usability aspects. Alerts on biometric changes should be shown adequately and integrated in the trading information process. In addition, the way to show stress level measurements should adapt to the trader's profile. We have considered the following elements to strengthen the usability of our system based on the principles enumerated above:

1. Adaptive stress time window: different traders will prefer/need feedback more/less often than others. We call this the "Adaptive stress time window".
2. Interruptions: according to Speier et al. [Speier, 1999], interruptions make information overload worse by reducing the amount of time one can spend working on the problem, which in turn leads to a feeling of being under pressure. It is therefore sensible that the information to the trader was shown in a continuous way in the same manner as the other trading information, avoiding interruptions in the trading process.
3. Secondary tasks: Serfaty et al. [Serfaty, 1998] found that with difficult decision tasks, subjects preferred to seek additional input from the easy-to-process opinion of a consultant versus raw data from a sensor probe. It may be of interest to show heart rate, skin temperature and other parameters, but they may overload the trader's attention capacity. Hence, we translate various sensing inputs into a simple stress level indicator.
4. Usability principles [Bevan, 2001]: The interface chosen to increase usability is a traffic signal. A traffic signal is a worldwide-recognized standard the user can easily understand and learn. The lights will indicate risk likelihood (red: the risk of a bad decision making is high, green: the risk is low and yellow where there is a moderate risk). The system allows different ways of operation (individual and group modalities). A coloured picture of people has been added below the warning lights to indicate the state of the group using the same parameters as for the individual information, e.g., red: the predominant state of the team is high stress; yellow: the team keeps a predominant moderated stress level and green: the predominant state of the team is low stress.

Guided by the considerations in this section, our previous research in sensor technology applied to the trading process and our experience in the development of a rule-based recommendation system for traders [Heyn, 2002], we arrive to a system that adds a new entry based on the biometric data gathered from the trader. With this data shown under a traffic signal resembling interface, the trader considers his/her own mental state as part of the information trading process, reducing the risk of bad decision making under stress.

In the following subsections we present in detail how the system works within the two modes of operation.

3.3 Individual-mode of operation

This section explains how the Self-Aware Trader system works in the individual modality. The architecture used and the main ideas behind the algorithm developed are included.

3.3.1 Architecture

The system has been designed as a modular architecture, which allows taking advantage of this work in other scenarios (emergency states, catastrophic situations, natural disasters, etc.) changing only the necessary parameters and modules according to the different contexts. Figure 2 represents the Self-Aware architecture in an individual-mode of operation with the main modules and its adaptation to the trading context.

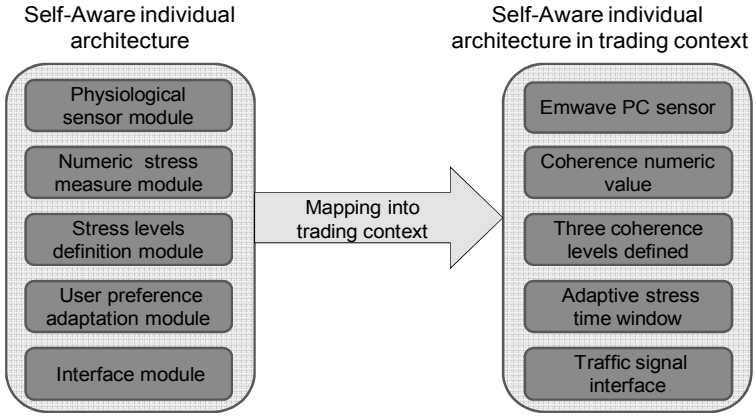

Figure 2: Self-Aware individual architecture into trading context

Considering the model principles previously presented, a brief description of the modules follows:

- Physiological Sensor Module: The first module is needed to acquire the physiological measures of the person. In our trading context this module works with the HeartMarth's sensor.
- Numeric Stress Measure Module: Depending on the data gathered (hearth rate, breath rate, temperature, etc.) within the first module, all data are processed to obtain only one numeric stress indicator. We extract this data (the coherence value) from the Emwave software (included with the HeartMarth's sensor).
- Stress Levels Definition Module: It defines the necessary levels of stress to be indicated to the user. The levels of coherence for each range will be defined in this module. We selected three coherence levels (low, moderate and high) for the trading context.
- User Preference Adaptation Module: It is necessary to allow the user to select the sensibility required in each circumstance. The adaptive stress time

window (trader's predominant coherence in a certain time window) is our way to allow the trader to manage it.

3.3.2 Software implementation description

The Self-Aware Trader software is a Java program that shows an interface using the metaphor of a traffic light system to feedback to the traders their coherence state. Using the traffic signal design, a red light represents a low coherence, yellow light is a medium coherence and a green light is a high coherence. The program uses as source data the measurements gathered through Emwave software via XML through a TCP port. The Self-Aware Trader software program accesses this port creating a socket and a buffer to read the data sent by Emwave two times per second. Among the data sent by Emwave is the coherence level (called "S" by the program) and our software extracts this information. This qualitative value depends on the current state of the trader and it could be one of three values: 0 (low coherence), 1 (medium coherence) and 2 (High coherence).

The Self-Aware Trader software allows adaptive measures creating a time stress window where the coherence level is saved during some seconds (depending on the trader selection) and once reached the time selected by the user the most frequent coherence during this time window is shown. We call this "predominant coherence" and it is calculated through the mode in statistics terms.

The user can choose the sensibility/size of this window between five options with a slider bar, where 1 implies 1 second (most sensible), 2 implies 5 seconds, 3 implies 10 seconds (and it is the default value), 4 implies 15 seconds and 5 implies 30 seconds (less sensible). Since the mode is not a unique value, and in a given set of data it could take more than one value, it was decided early on that if such a case were to happen, the system would show the previous state.

According to the predominant coherence in the period of time selected in the stress time window we display the appropriate colour in the traffic signal interface: red, yellow or green. A brief sketch of the process described above in a graphic way is presented in Figure 3 with a stress time window of 5 seconds (10 measurements).

3.4 Group-mode of operation

One of the most important problems in trading is the difficulty to realistically gather in real-time an indicator of the stress level experienced by the market, e.g., an immediate measure of the collective stress level that traders operating are experiencing.

According to Lori [Lori, 2002] the movements of the stocks markets are very connected with the emotional state of the collective emerging opinion and reaction of traders that are operating in the market itself. Even a study [Bollen and Zeng, 2010] using the social network twitter predicts the movements of the stocks markets. The study concludes that there is a correlation between the emotional status of the users as reflected in twitter and the state of the stock market. However, it does not provide a real-time correlation and hence is of very limited help.

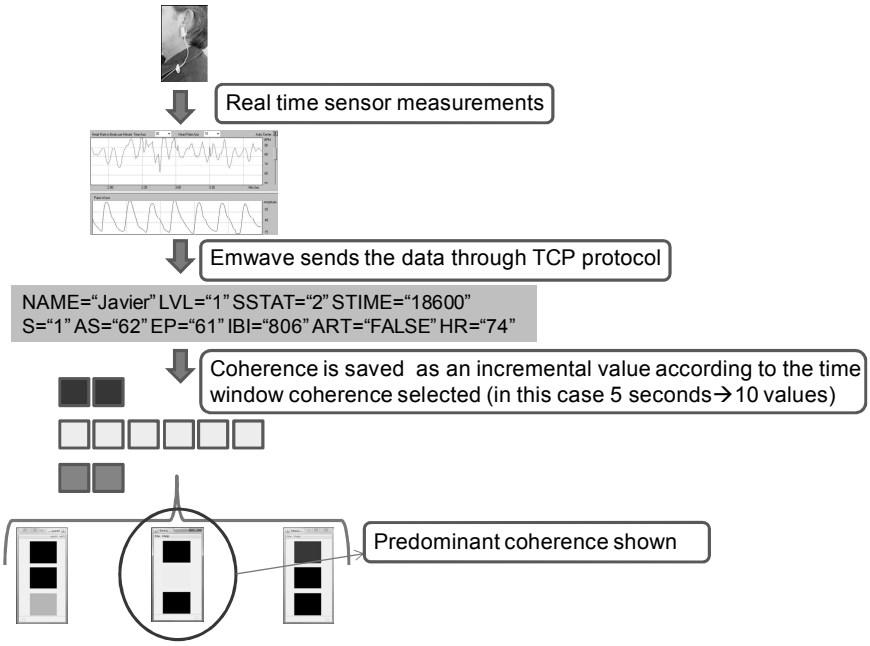

Figure 3: Self-Aware Trader software algorithm (5 seconds stress time window)

The advantage of the Self-Aware Trader system in group-mode operation is that it can obtain this correlation in real-time. Therefore, as in the individual mode, our goal with the system is not to reduce the stress level of the traders, it is to make them aware of it. In this sense, if a trader is able to see at the same time his/her state and the statistical picture of the state of his/her partners, this allows him/her to compare and detect critical moments in the market. Furthermore, the collective knowledge of a group of traders has an indirect application for trading companies. This collective comparison of awareness opens up a new way to facilitate the supervisor's task of managing his/her group of traders. A supervisor could see whether a specific trader is transitioning to an unsafe decision making zone when the rest of the team is in a safe zone.

It is necessary to take into account that we made some decisions regarding privacy. These should be revised for other contexts:

- The trader is aware about the collective state (through a group of people picture) and his/her own state through the traffic signal. In this way, we show the information in an anonymous way.
- In our design, the supervisor can see the levels of the collective state and of all the users in an individual mode. Currently the users appear by IP number, but depending on the country law and the privacy policy the identification of the user may be shown in more detail or even not shown at all.

The architecture and software implementation for the individual-mode of operation have been enhanced to cover the group features, and are described hereafter.

3.4.1 Architecture

We extend the original individual architecture with the necessary group elements. In order to keep the modularity of the system, a client/server model architecture has been developed for the group-mode operation. Figures 4 (client) and 5 (server) show both modes of the architecture and their mapping into the trading context.

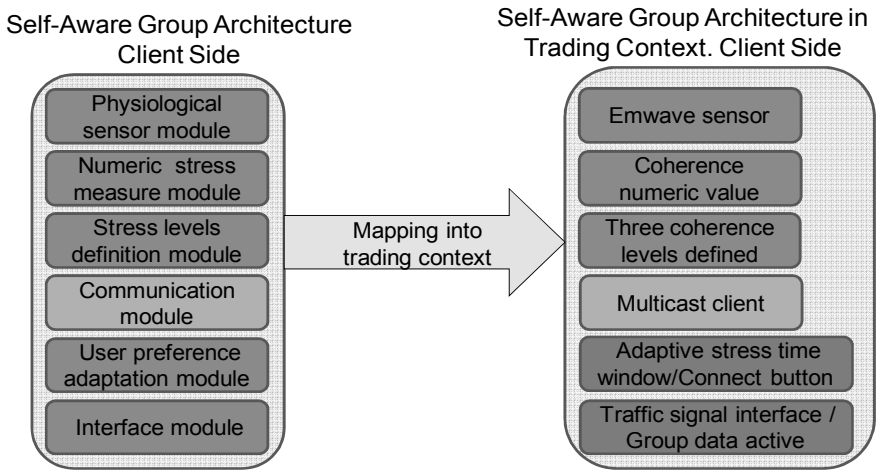

Figure 4: Self-Aware group architecture into trading context. Client side

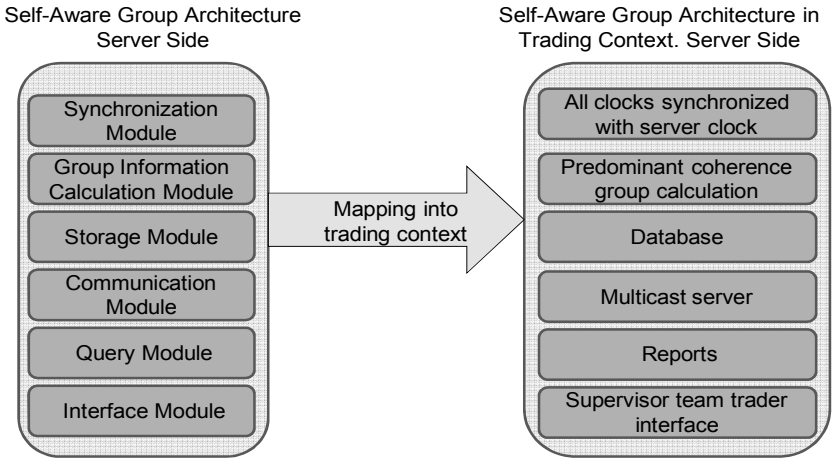

Figure 5: Self-Aware group architecture into trading context. Server side

Taking as a reference the Self-Aware individual architecture, only a few changes are needed to reach the client side architecture. A communication module is inserted (light grey) to manage the communications in a bi-directional mode (every person sends his/her own state and receives from the server the predominant state of the group). The user preference adaptation module has been updated adding a button to connect and disconnect from the group leaving this decision to the user. If the trader disconnects from group mode, the client does not send information about his/her own state and does not receive information about the group (working in individual-mode of operation). In this situation the supervisor will know in real time which client is disconnected from the group and how long this situation has lasted for. These changes are indicated with wider boxes in Figure 4.

The server architecture is focused in calculating the predominant group state and in sending it to both, clients and supervisor. The supervisor also receives the individual state of each trader. In order to achieve this goal, the server architecture has the following modules:

- Synchronization Module: It is necessary to keep everybody synchronized to ensure reliable information. In the network of traders all clocks are synchronized with the server clock.
- Group Information Calculation Module: the server processes the information sent by the clients in order to calculate the group information. This is then sent back to the clients and to the supervisor. This information in our trading context is the team predominant coherence.
- Storage Module: It is very useful for the supervisor to study the reaction of the team in previous situations in order to be able to manage it. For this reason it is valuable to save the data of the team members.
- Communication Module: This module will manage the communications in a bi-directional mode. The server will receive from every client their state and will send everybody the predominant state of the group. A Multicast server is used for the trading context.
- Query Module: It is necessary to allow the possibility for the supervisor to make some queries. This module processes these queries. Thanks to this module the supervisor will be able to see the state of the traders in different periods of time during the trading session.
- Interface Module: Depending on the context, the interface could be totally different, but in principle it should be only accessible for the supervisor. The interface shows by default all the traders' state in real-time. It is also possible to show the team's state in some specific periods thanks to the query module.

3.4.2 Software implementation description

To add this functionality to the Self-Aware Trader software a multicast network has been programmed using a client-server model. The trader starts to work in individual mode and when he/she wants to join to the group he clicks a button in the traffic signal interface (connect/disconnect).

While the trader is working connected to the group, the warning lights continuously show his/her own state. At the same time, the group state is shown with a picture of people that is changing colour (like the warning lights). Furthermore a

number close to the picture indicates the amount of people that are connected to the system. When the trader is operating in individual mode this picture appears in grey and no number is shown.

An example is presented in Figure 6. The picture on the left shows an interface in individual mode where the trader is in high coherence (lower square in green). In this case since the group mode is disconnected, the picture of the team is in grey and the information box with the number of the traders connected to the system is empty. The picture on the right shows the interface in group mode (connected) where the trader is in medium coherence (second square in yellow) and the rest of the traders, a total of 28, are in high coherence (green colour in the team's picture). In both cases the stress time window is selected in position 3 (medium sensibility).

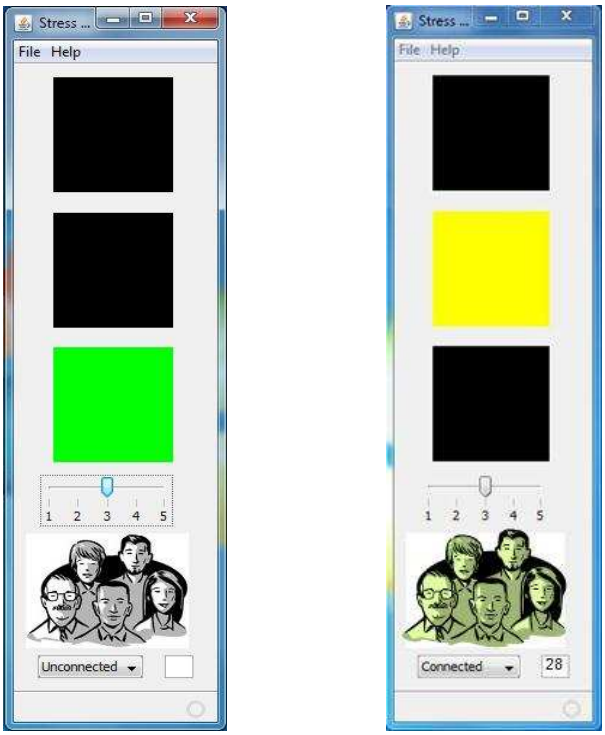

Figure 6: Individual and group-mode. Client framework

All traders within the group send the current coherence level every second. A synchronization process is necessary in order to keep consistency in the group coherence.

With all the data received from the traders, the server calculates the predominant mode among all traders in the group and sends this value and the number of traders connected. Furthermore the server saves all data received from every client. This is in order to have the necessary information to provide different statistics (useful for example for the supervisor) of each trader and have a historical data logging of every session.

This group mode is oriented to an investment bank where it is common to have a lot of traders in the same network of computers. In this sense, a framework has been developed in the server in order to allow supervision of employees (Figure 7) where it is possible to see the following information (refreshed every second):

- Traders connected: Each trader appears identified by the IP of his/her workstation. The colour depends on the current coherence state of the trader. Note that the first line (Global Server) indicates the coherence of the group.
- Percentages per state: The percentage is calculated based on the time that the trader is in every state. In this sense, it is possible an easy monitoring of every trader.
- Connected Time: The amount of time that every trader is connected to the group system.
- Query button: A combo box button has been implemented in order to allow making different queries to the database based on the session time. By default the query button is in "Full Session Time" status showing the real-time.

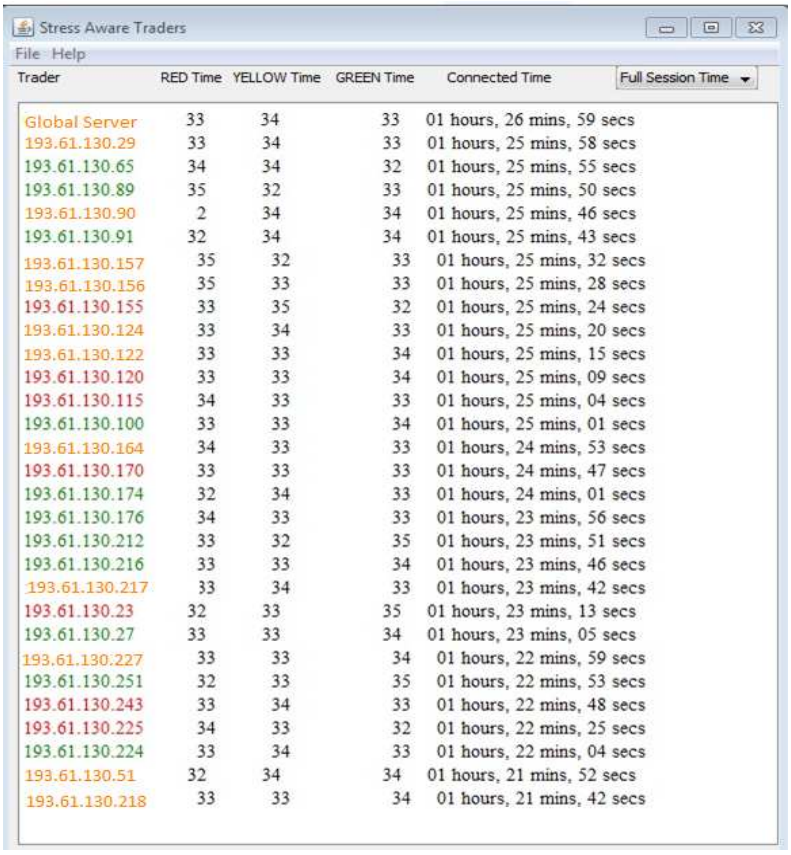

Figure 7: Self-Aware Trader software. Server framework

The next section describes the tests carried out with some real traders to validate the system and a discussion of the results is shown.

4 Validating the system

We report two cases of study, a home trader and a trading company. The first one consists of a trader working in the financial market from a computer through the Internet.

4.1 Home trader

The objective of this test is to run in an individual mode the Self-Aware Trader software and to answer the following questions:

- Is there really stress in trading?
- Can the Self-Aware Trader system help the trader?

The equipment used by the trader is a laptop with internet connection, the HeartMath stress relief system (stress sensor), the Emwave Pc (V1.0) software and the Self-Aware Trader software. The experiments have been done in the Spanish financial market, and all necessary information for the trading process (price of shares, charts, news...) has been extracted from Infobolsa web (http://www.infobolsa.es/). The trader who deploys the experiment is a non professional trader, but has 10 years of experience in this market.

In order to be able to analyse all the data, we record the individual coherence graphics generated by Emwave software. In these graphics, the time is represented on axis X and the accumulated coherence score shown in axis Y. This accumulated coherence score grows when the coherence is in safe mode (coherence level = 2), when the coherence enters in an unsafe mode (coherence level = 0), it decreases, and when the coherence is in medium level (coherence level = 1) it increases or decreases depending of the previous state. The minimum accumulated coherence score is 0 (no negative values used).

The reader should be aware that these individual graphics were never seen by the traders but we decided to include them here in order to provide a time-line tracking of the experiment and evidences of the appropriateness of coherence as a variable to monitor traders' stress, thus validating the Self-Aware Trader system. In these graphics it is possible to see how the influence of the news, external events (as a phone call) or even the pressure of expected stressful hours have a high impact in the trader's stress level.

4.1.1 Experiment with IBEX 35 Shares without Self-Aware Trader Information Support

With this experiment we want to know if in the crucial moments of trading with shares (buying and selling), the trader's coherence level is affected and how that changes the decision making process.

In this experiment, the Self-Aware information is not shown to the trader. However we record the coherence of the trader with Emwave software in all the session to see the relation between his coherence and the trading done. The

experiment duration is 1hour 30 minutes. In the Table 1, we can see the operations done by the trader and Figure 8 shows the trader's coherence during trading time.

Buy time	Share	Price	Sell time	Price
12:00	TELEFONICA	17.380	13:23	17.390
12:05	BBVA	10.970	13:22	10.980
12:06	SANTANDER	10.305	13:14	10.32
12:20	ABENGOA	20.10	13:04	20.27

Table 1: Share Trading

Figure 8: Coherence score experiment 1

We can see that in the first 20 minutes of buying operations the stress of the trader prevents achieving good coherence levels (the lines in the graphic remains low). Later on, the next half an hour of the experiment shows the time when the trader was waiting for the optimal selling point and that inactivity allows a high level of coherence to be reached, which is reflected on the graphic growing. Finally, the accumulated coherence stops growing when the trader tries to sell the shares at an optimal prize. The conclusion of the experiment is that the trader's body and coherence changes naturally reflect the crucial moments (buying and selling of shares).

4.1.2 Experiment with IBEX 35 Index Futures without Self-Aware Information Support

In this experiment, the trader operates with "futures" in IBEX-35 Index. This index has a prize and it changes depending on the movement of the companies that compose it. If the trader thinks that this index will go up, then the trader can buy an IBEX-35 "future" and sell it when the trader thinks that the index will go down. In the opposite case then the trader can sell a "future" and buy it when he/she thinks the market could go up. In this operative each point up or down represents significant money and the movements are very fast (unlike in the shares trading). It forces traders to continue operations and increases the stress moments.
Table 2 indicates the operations most representative for the experiment in 1 hour 30 minutes. Taking into account that the first 20 minutes the trader considers not to make

any operation, but the Emwave software is running and recording the coherence level. In this experiment, the information for Self-Awareness is not shown to the trader.

Open Time	Prize Open	OP	Close Time	Prize Close	OP	Points
16:21	10808.30	BUY	16:26	10830.20	SELL	+21,9
16:27	10843.10	SELL	16:31	10848.30	BUY	- 5,2
16:32	10849.90	BUY	16:39	10816.60	SELL	-33,3
16:45	10801.00	BUY	16:49	10828.20	SELL	+27,2

Table 2: Future Trading without Support

In Figure 9 (a) we can see the coherence score during the trading process and in Figure 9 (b) the IBEX-35 chart. This chart represents the movements of the Index's prize (axis Y) during the session time (axis X) represented by the hour.

Figure 9: Coherence Score experiment 2 (a) and Chart of IBEX-35 (b)

We can see a frequent trading risk situation, at 16:27. The trader believes that 10843 is a good level to sell (corresponding with the first top of the IBEX graphic), then the trader sells. However, IBEX go up some points breaking the trader strategy, so the trader buys losing some points. The trader tries immediately to change the strategy, he knows that he was wrong and does not want to lose this crucial moment, now the trader is considerably stressed and his decision making is unsafe. The market has done a "false break" (circle in red in Fig 9 (b) and the trader has bought in a rushed decision (circle of Figure 9 (a). The trader loses 37 points in total. The Self-Aware information could have helped to avoid this mistake.

4.1.3 Experiment with IBEX 35 Index Futures with Self-Aware Trader Information Support

This experiment is conducted to show the favourable impact in the trading process when the trader has access to the information that makes him/her more Self-Aware. This session was the most difficult session for trading during the experiments, due to the Greece debt default news [Fanders, 2010] at the time of the exercise.

The Index suffered abrupt variations in seconds. Table 3 indicates the operations in 1 hour. Take into account that the trader in this case is Self-Aware of his own state with the Self-Aware Trader software. In this table, the number of sequence of operation has been added for a better tracking.

In Figure 10 (a) we can see the coherence score; in this case we have added numbers corresponding just with the 8 moments when the trader made a decision to buy or sell. Figure 10 (b) shows the IBEX-35 chart.

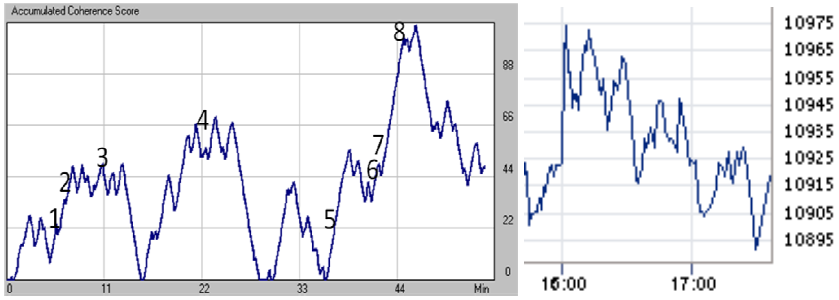

Figure 10: Coherence score experiment 3 (a) Chart of IBEX-35 (b)

Open Time	Value Open	OP/nº	Close Time	Value Close	OP/nº	Points
16:25	10948,60	SELL/1	16:28	10948,60	BUY/2	0
16:31	10947,30	BUY/3	16:44	10952,80	SELL/4	+5,5
16:59	10921,70	BUY/5	17:01	10934,20	SELL/6	+12,5
17:03	10906,20	BUY/7	17:07	10923,70	SELL/8	+17,5

Table 3: Future Trading with Support

In this session, we can see the high impact of the news and the abrupt movements of the Index in the coherence of the trader. However, in this case, the trader has access to feedback from the system on his coherence levels and based on that the trader decides to make decisions only when he believes to be in a safe state avoiding, in this case, bad operations. In this case all the decisions were made with the green light in the traffic signal interface. Three decisions about the sell in point 4 and the buy in point 5 were avoided by the trader because he saw a constant red light during this period (More than 7 minutes). The trader commented us that it is in these kinds of frenetic market contexts the support offered by the system is more clearly appreciated.

From the three experiments above presented we can conclude that stress has high impact in traders and the decision making for traders with system support is safer.

4.2 Company test

This section reports on the most important validation exercise where we carried out tests in the company Louis Capital Markets UK in London. Louis Capital Markets is a global independent agency broker-dealer. Some of the traders kindly allowed us to test our system and we gathered some important data, which will be shown in this

section. It is worth mentioning that the company FCC Performance (New TakeTen Ltd) licensed by the HeartMath Institute supported us by lending all the sensors necessary to make this test possible.
The objective of this test was to answer to the following questions:

- Are traders influenced by collective state?
- Can Self-Aware Trader system in group mode help traders?

The trading operations are not described due to confidentiality reasons so the traders' identity and details of the operations are protected.

The laptop's screen showed the Self-Aware Trader traffic signal interface allowing the trader to be aware of his/her own state (Figure 11). A wireless router was set-up in addition to the normal traders' network to allow communication between the Stress-Aware Clients and Server, thus avoiding further disturbance to the normal business operation of the company.

Figure 11: System test setup with Self-Aware Trader system

4.2.1 First test - Various traders using the system in an individual-mode

In these experiments the traders wore the sensor attached to the ear and work with their normal process plus their stress level information during 45 minutes per experiment. This first test was divided in two moments, one aimed to capture data in a quiet moment and another to capture data in a frenetic moment.

4.2.1.1 Quiet Martet

About 11:00 am in the morning traders indicated that in these moments the market is quiet without many operations, so we took advantage of these moments to perform the test.

We show below three coherence graphics of three different traders (Figure 12) that were involved in the same trading process (same market, same moment). We include in these graphics the most predominant colour of the traffic signal shown to the traders ("G" implies green, "Y" implies yellow and "R" implies red) in different periods within brackets and the moment when some external event, e.g. relevant financial news, appeared.

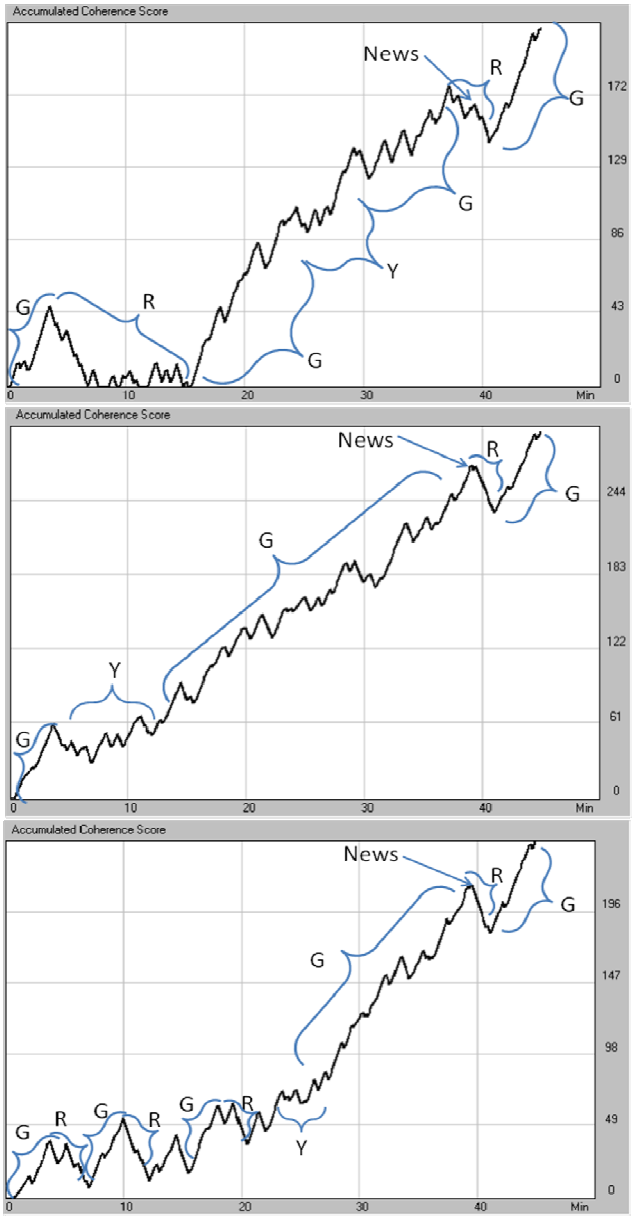

Figure 12: Traders 1, 2 and 3 coherence graphics. Quiet market

The graphics of the traders' coherence during this test have the same shape. The ascendant coherence scores make sense due to the quietness of the market in this period. However each trader has a different perception of the risk in each moment and it is possible to observe this in some periods in Table 4.

Trader	Safer Periods. Most Green Light	Moderated Periods. Most Yellow Light	Riskier Periods. Most Red light
1	0-4,15-21,28-40,42-45	22-27	5-15,38-41
2	0-4,15-40, 42-45	5-15	38-41
3	0-4,8-10,15-18,28-40,42-45	22-27	5-7,11-13,19-21

Table 4: Information example group test. Similitude and differences

During the first 5 minutes the three traders are in a low risk state showing in the Self-Aware Trader traffic signal interface a green light, however while trader 1 in the next 10 minutes most of the time received a red light warning, trader 2 keeps a moderated risk state showing alternatively yellow and green lights and trader 3 has continuous variations from red to green. After that, the coherences of the three traders are similar and most of the time, green and yellow lights are shown until the minute 38 of the test where the three traders suffer a potential increase in risk. This moment coincides with some news being released to the market. At this time the traders' coherence enters a decreasing state and recovers in the last minutes of the test.

4.2.1.2 Frenetic market

Although the graphic shapes (Figure 13) are different from the quiet market, we also find a common pattern in the three figures. During the first 25 min. of the test (from 14:15 to 14:35) where more operations are performed, the traders stand under more pressure and continuous decision making is needed.

In these moments the information facilitated by the Self-Aware Trader is more valuable matching up the ascendant lines with a green light in the traffic signal interface being a safer state for the trader to make decisions and the descendent lines of the coherence with red light and informing the trader of the less safe decision making state. In Table 5 we have selected some of these periods as an example.

Taking into account the data gathered shown in the previous figures and tables, we can observe that the same team working in the same market at the same time have similar graphic shape due the correlation in their trading process (as it is possible to see around minute 40 in both markets). However, every person has different biometric measures producing different coherence graphics (evidenced in the first 15 minutes), and it is possible to observe how trader 3 in this test supports more stress than his/her partners, so the individual information is a valuable data in all the session for the trading independently of the state of the market.

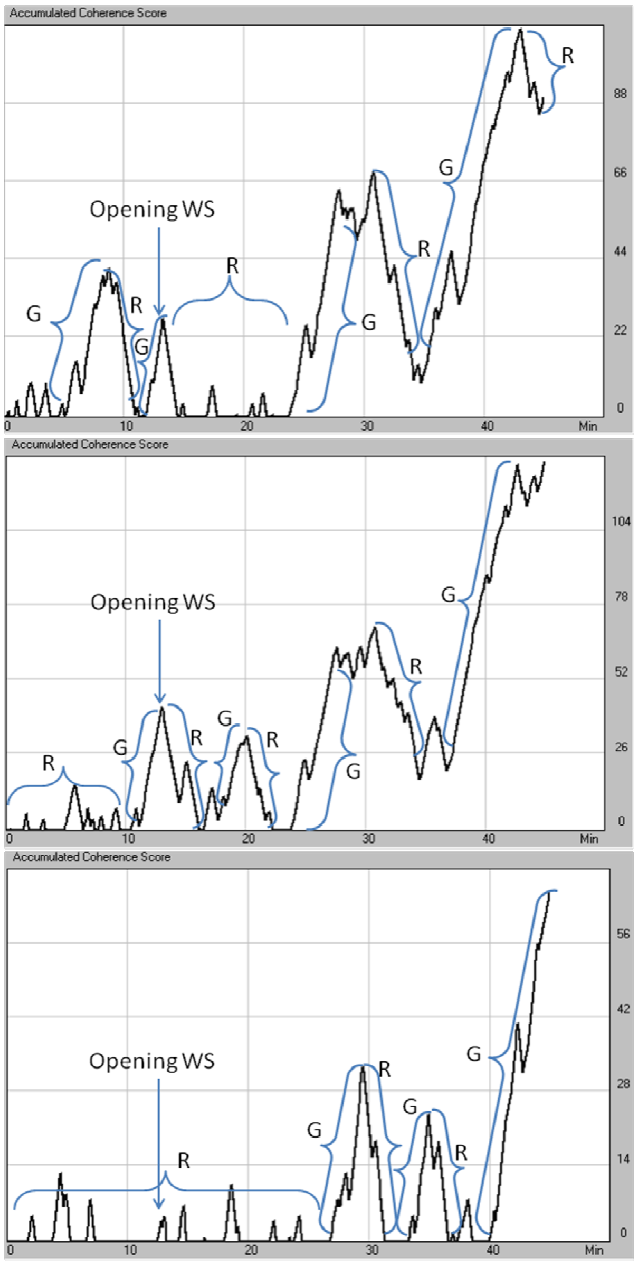

Figure 13: Traders 1, 2 and 3 coherence graphics. Frenetic market

Trader	Safest Periods. Most Green Light	Riskiest Periods. Most Red light
1	5-8, 12-14,26-29,36-42	9-12,15-25,30-35,42-45
2	11-13,18-20,25-30,36-42	0-10,15-17,20-24, 31-35
3	26-30,32-35,40-45	0-25,29-31,36-38

Table 5: Safer and riskier decision making periods

4.2.2 Second test - Various traders using the system in group-mode

In this case, the traders are working with the Self-Aware system in group-mode, so it is possible for the traders to get the following information:

- Their own state as in individual-mode shown in the traffic signal interface
- The predominant market perception of the group shown with the group picture
- The traders connected to the system with a number displayed just close to the group picture

The information of the predominant stress of the group tells to the trader whether he/she is correlated with the current team's stress profile or whether his/her state is different. In this case safe decision-making could be at risk (indicating either overconfidence or undue levels of worry).

In the same way for a supervisor, when one trader is different to the rest of the traders for an unusual period of time it is easier to detect that his/her decision making could be compromised.

Figure 14 shows the graphic coherence of the traders in this test during 45 minutes. In this case a big size letter is used to indicate the colour of the predominant coherence in the group and a small size letter is used to indicate the colour associated with the trader's own state.

During this test, one of the traders (trader 2) showed a red warning for an extended period of time after a phone call (from minute 20 to minute 31), which is reflected in a prolonged decline of the coherence score in the graphic. However, in this period the rest of the traders maintain a balanced level. The trader realized that prolonged inconsistent information between his/her state and the team's state derived in a compromised period for decision making.

This is the situation where the Self-Aware Trader system working in group mode shows its potential. It is able to detect and feedback to the trader and the supervisor that the decision making of this trader could be at risk. It is possible to see this in a clearer way in Table 6 where some periods of the session are highlighting the moment where trader 2 keeps a red signal during 10 minutes in opposition to his/her partners.

Figure 14: Traders 1, 2 and 3 coherence graphics. Group-mode

Trader	Period 0-10	Period 20-31	Period 35-45
1	Green	Green	Green
2	Green	Red	Green
3	Green	Green	Green
Group	Green	Green	Green

Table 6: Information example group test. Period time

While trader 2 went through an unsafe decision making period, a query in the server was generated with a summary of the last 5 minutes (Figure 15). Here it is possible to see that trader 2 (IP 104) spends most of the time in red (88%) while the other traders were in green (65%).

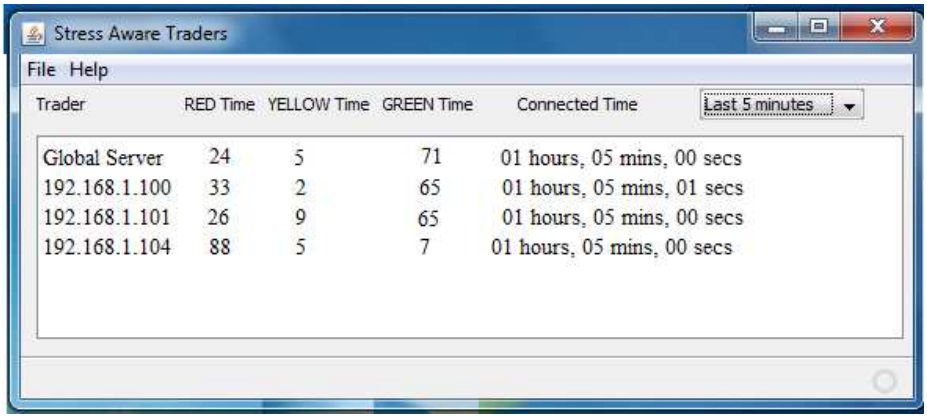

Figure 15: Query last 5 minutes

From the two tests above presented we can conclude that the collective state has a high impact in traders. The Self-Aware Trader system helps traders in individual and group mode. The system is also useful to manage a traders' team from the point of view of the supervisor.

4.3 Evaluation and discussion of the results

After the tests, the following conclusions can be drawn:

- Previous losses, fear to lose a great trading movement, news, time restrictions, and many other factors have high impact in the trader's decision making. Evidence of this can be seen in Figure 12, after a prolonged time in green, a news item in minute 38 has a clear impact in the three traders.
- The more difficult the market is, the riskier the trader's decision making is and the more important for the traders to be Self-Aware of their own stress levels. This is evident as it is in frenetic markets (Figure 13) where traders find the Self-Aware Trader System more valuable.

- The Self-Aware Trader working in group modality adds worthwhile information both for the trader and for the supervisor. Figure 14 shows trader 2 on a red light period during 10 minutes, the trader realized that their partners were in a complete different state and this trader later commented to us that without the Self-Aware information they would not have realized that their decision making was compromised.
- The Self-Aware Trader also covers a gap in the managing of the teams. A supervisor may believe to know the state of his/her team. Due to this circumstance, sometimes a supervisor may discover too late that one trader has problems. Usually the problems are discovered after high losses. With the Self-Aware Trader system the supervisor is able to see in real-time the state of his/her team and monitor in a more efficient way the trading session.

The follow up action from management when a trader is clearly in a risky situation should be open to the rules of the company and the criteria of the trader and the supervisor. Some possible actions could range from launching a decision support system meanwhile the trader is in a risky state, to suggesting a more intensive supervision of this trader, or even automatically stop the operations of this trader.

5 Conclusions

Increasing profit in the financial markets is one of the most researched and studied subjects. The focus of most of these studies has been on creating systems to try to predict the movements of the financial markets and take advantage of those movements. However, the financial markets change on a daily basis and consequently, the systems that work today may not be effective in the future.

The latest systems that are being used in the market are the high-frequency trading systems. These systems are based on programs running on high-speed computers that analyze market data, using algorithms to take advantage of trading opportunities. These previous attempts of widespread involvement of technology replacing humans have caused negative consequences. For example, The United States stock market crashed on May 6, 2010. On that day, the Dow Jones Industrial Average plunged to its largest intraday point loss and this was attributed to the use of these systems.

In this paper we explain a system we have developed under the principle that the trader is the main actor in the role of the trading process and all systems should be there to support the trader. As it has been previously found, the illusion of control prevents the trader from realizing that he/she is entering a phase of unsafe decision-making. Self-Aware Trader software blends technology, physiology and psychology to feed back to the trader this important information. The system has been extended into supporting a group of traders and it has been validated in several scenarios, including an investment company. The experiments we carried out give evidence that providing support to traders to raise their emotional awareness is helpful and welcomed within that profession.

In addition, the deployment based on a general architecture enables us to test the system in other stressful contexts adapting it to the peculiarities of the environment to test. Currently we are testing the Self-Aware system with pilots using the flight

simulator program in Swiss Air and preliminary results are supporting our conclusions in the trading environment.

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