xDELIA Project Number 231830

Xcellence in Decision-making through Enhanced Learning in Immersive Applications

Document Name:	**Exploratory studies (D13-2.2)**
Document Wiki:	http://xdelia.fzi.de/index.php/D13-2.2_Exploratory_studies
Document Date:	*March 5th, 2010*
Document Owner:	*xDELIA Consortium*
Document Author/s:	*Shalini Vohra, OU* *Kristina Schaaff, FZI* *Caroline Jähnig, FZI*
Contributors:	*Mark Fenton-O'Creevy, OU*
Deliverable Number:	*D13-2.2*
Work Package:	*WP2*
Deliverable Type:	*Report*
Version	*1*

COPYRIGHT AND CONFIDENTIALITY NOTICE

Appendices

Document Name	Date
Appendix A. References	February 5th, 2010

Contents

Figures

1 Introduction

1.1 Document Purpose and Scope

The xDelia approach, in WP2, to designing technology enhanced learning approaches to improving financial decision-making among traders and investors has two phases. In this first phase we are investigating links between emotion regulation, financial behaviour and decision-outcomes. This work does build on prior research findings but we need to build a more detailed understanding of these relationships before moving on to design learning applications which will seek to improve decision performance by supporting improvements in emotion regulation. This first phase involves both exploratory work and substantive studies. The purpose of the exploratory work is to a) provide confidence that our approach aligns with the expectations and understanding of key stakeholders; b) ensure a clearer understanding of the context of application, not least in ensuring that we can effectively characterise key elements of trader and investor performance and characterise the dynamic role played by emotion over a 'performance episode'; c) ensure we understand how to translate our research questions into experimental and field study designs; d) to appropriately test key sensor technologies in both experimental and field settings; e) provide early results to establish key problems to be solved in learning game design.

The purpose of this document is to give an overview of the results in Work Package 2 of the exploratory work undertaken to date with traders, managers of traders, and investors as well as the exploratory studies on sensors and economic experiments. The document presents in a succinct manner, the exploratory studies undertaken as well as the key findings from the same. The document further goes on to discuss the implications of the exploratory work on the in-depth studies. The document concludes with a summary of the implications for in-depth studies.

For the sake of brevity and accessibility we do not devote much space in this report to the theoretical underpinnings of our work (eg detail description of theories of emotion regulation, the basis of the link between emotion regulation and heart-rate variability etc.). This can be found in D6-6.1 'Project-wide multi-disciplinary state-of-the-art'.

1.2 List of Acronyms

ECG	Electrocardiogram
EDA	Electrodermal activity
PC	Personal computer
SCR	Skin conductance response
UK	United Kingdom
WP	Work package

2 Emotions and emotion regulation in the financial decision making of traders and investors

Exploratory work with traders, their managers and investors was carried out in order to investigate the relevance of emotions and emotion regulation for financial decision making performance. In order to explore the relevance of the same from the point of view of the traders, interviews were carried out with 16 traders and senior managers from two leading investment banks. Further in order to get an understanding of the investors view, findings from an ethnographic study carried out at Saxo Bank's 5 locations globally and comprising of 23 investors as well as observation of 35 investors at 8 meetings of 4 UK based investment clubs, were taken into consideration. The traders interviewed for the research ranged from novice to expert. A later supplement to these findings will be based on interviews with active investors who trade on their own account using the Saxo Bank trading platform.

Phase one of WP2 addresses the following key research questions:

1. Do emotions and their regulation influence financial decision-making performance?
2. How much do emotions and their regulation influence financial decision-making performance compared with other key factors?
3. Can emotion regulation be improved through training, in ways which improve human performance?

The exploratory work has begun to provide some relevant insights. The next section discusses findings relevant to these research questions drawn from the initial exploratory studies with traders and investors.

2.1 Does emotion regulation strategy influence financial decision-making performance?

The research undertaken across two leading investment banks highlighted the impact of emotions on the performance of traders and investors. Traders were fairly open in talking about their experience of emotion at work and it was clear that traders and their managers are often preoccupied with the effective regulation of emotions and believe that emotion regulation does have a bearing on their financial decision making performance. The impact of emotions and the ways in which they are regulated was seen as having a bearing on the performance of the traders and investors. This impact manifests itself in several ways:

1. **Path dependence**: The interviews with traders suggest that the emotional impact of trading and lack of proper emotion regulation may manifest itself in the form of path dependence, where money lost in earlier trades continues to influence trades undertaken thereafter. Path dependence may influence the traders in terms of: increased risk taking to make up for the recent unpredicted gain or win; undertaking trades/investments that are deemed unwise; reduced confidence or unjustified risk aversion causing them to shy away from trades/investments that represent valuable opportunities.

2. **Forced trading/investing**: The emotional impact of missed opportunities or non execution of good ideas was found to manifest itself in the form of forced trading. Forced trading/investing is the act of entering trades or investments which the trader or investor does not have a lot of conviction in and tends to be a knee jerk reaction to make up the real or notional loss. Such trading or investing tends to be impulsive panic driven rather than opportunity driven. The seemingly missed or lost opportunities lead to emotionally driven reactions in an attempt to recover the real or notional amount of money lost.

3. **Trading from the gut**: Many traders recognised getting swept up by the noise (random fluctuations) in the market and thereby not backing ones own convictions and rational decisions. Traders frequently recognised the relevance of one's guts or conviction and recognised as one of the most important tools for effective trading decisions. Inability to back one's own convictions was identified as one of the worst feelings in trading and investing. Losing money or missing opportunities through failing to back one's own convictions had a much stronger and longer lasting negative impact then losing money on convictions that didn't work out the way that was anticipated. Intuition and 'gut feel' were seen by many traders to be extremely important for trading and investing. The top traders were identified as one's that have a *feel* for the market. However intuition or 'gut feel' was commonly seeing as having its core or at least part of its core in news or information. It was also clear that many traders felt that a critical engagement with intuition is very important, bringing analysis and data alongside hunches and gut feel, accompanied by a willingness to be self critical and 'honest with yourself'.

4. **Self doubt**: When money is lost over a period of time then confidence gets eroded and self doubt becomes a major obstacle to overcome. The vicious cycle kicks in, of having lost money and being wary of losing more money, as a result of which even more money is lost. It was considered extremely challenging both emotionally and mentally to be able to avoid this vicious cycle and its implications on trading.

5. **Personal Honesty**: Getting attached to trades or investment and failing to see the wrong decision was identified as a common phenomenon. When this happens, pure emotional attachment and resistance to admit one's mistake becomes the basis of staying with a trade or investment. Such a situation tends to become increasingly worse as the longer such a trade or investment is stuck to, the more money is lost and as a result of which the trader or investor is under even more pressure to make up the loss. This in turn leads to even more resistance to exit the trade or investment.

6. **Self discipline**: Several traders spoke about the need for self discipline in trading and the adverse impact on performance where this discipline is not maintained. A common form of ill discipline seen among traders is not sticking to the planned exit strategy and the tendency to become *emotionally* attached to trades. This emotional attachment manifests itself in terms of the traders not having the discipline to exit a bad position. Poor discipline is also reflected in not being ill disciplined with risk taking. Commonly traders suggest following a heuristic that the amount of risk taken should be linked to the amount of conviction that they have in the trade. Putting on a trade in too large a size and losing money on it when the trade was one that was not very promising in the first place is an extremely disheartening and painful experience. "Discipline" was also emphasised by all 23 investors in the ethnographic study carried out at Saxo Bank and was an area of interest among the respondents.

7. **Anticipatory emotions**: Being emotionally ready in preparation for an important news event or anticipated market activity was a common phenomenon among traders. This emotional preparedness was commonly reflected in prepping oneself by recognizing the likely emotionally upheaval the event will cause and so planning strategies with a rational mind ahead of the event and attempting to stick to those once the news has been released.

Some also spoke of consciously raising their emotional arousal to focus and prepare for trading.

Thus, in brief, the interviews undertaken with the traders suggested that they:

- consider the down-regulation of non-relevant emotions to be important in avoiding non-rational bias in trading
- place great importance on self-regulation (self-discipline)
- place great importance on avoiding illusion (personal honesty)
- often consider 'gut feel' about trades or trading conditions to provide important information

The interviews in particular highlighted the role of anticipatory emotions and cognitions during a performance episode and the need for an optimal level of arousal to achieve task focus and rapid action. Based on the first exploratory study and previous work with traders, the unfolding of a performance episode around a planned news event can be tentatively described as reflected in *Figure 2.1*. *Figure 2.1* presents an ***evolving*** understanding of how emotions play a role in decision making of traders and investors.

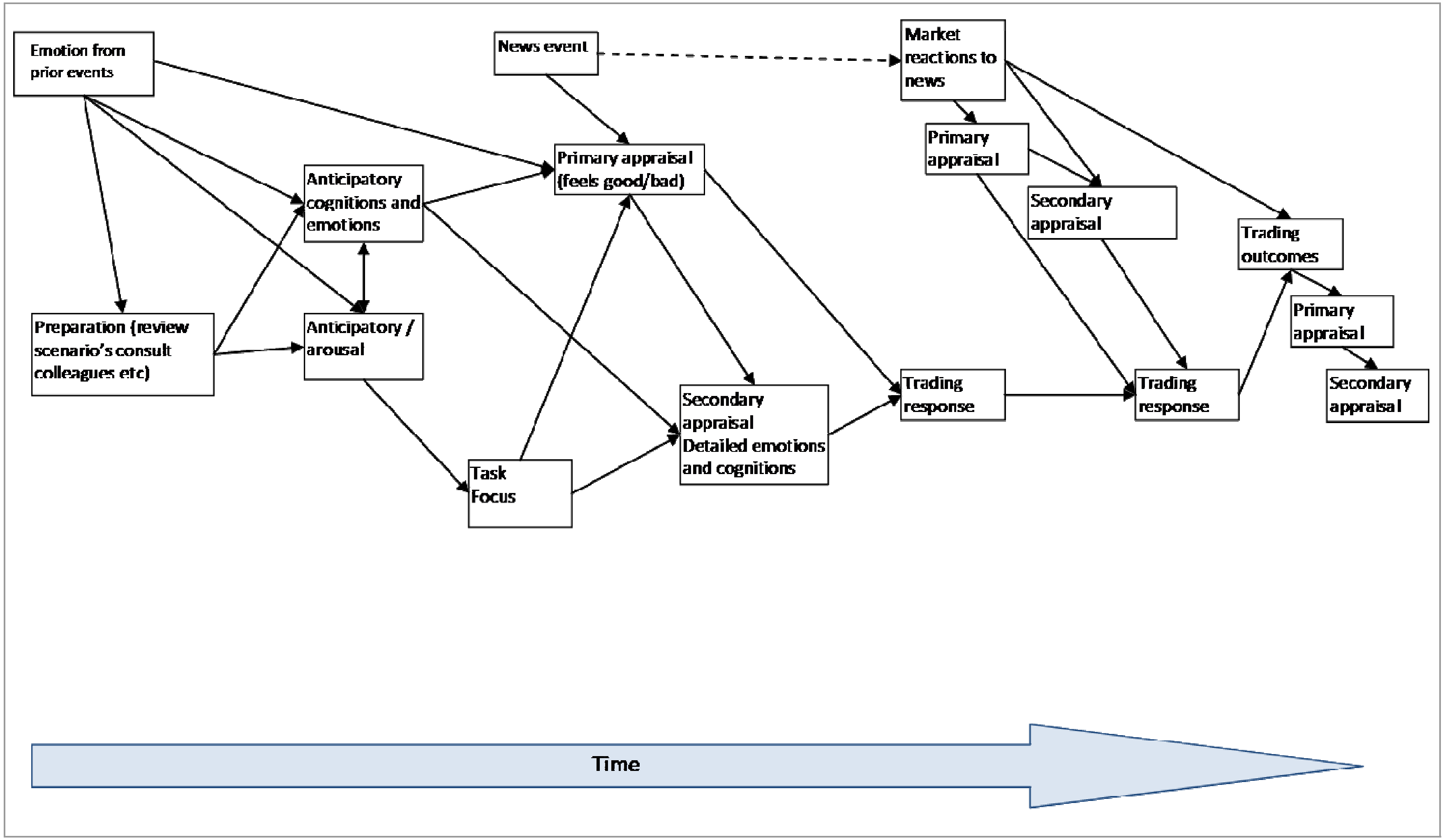

Figure 2.1 – Affective anatomy of a trader performance episode around a planned news event

A quick inspection of the process (*Figure 2.1*) makes it clear that emotion regulation comes into play at multiple points:-

1. In down-regulating prior non-relevant emotions.
2. In modifying anticipatory emotions.
3. In management of attention implicated in the need for task focus.
4. In primary and secondary appraisal of news, market reactions, and trading outcomes.

A similar picture could perhaps be drawn for an investor's trading, but would not necessarily centre on news events. A planned follow-up interview study with a group of Saxo investors should help tease this out.

Thus in brief, the exploratory interviews undertaken with traders and the ethnographic work with investors confirmed the influence of emotions and emotion regulation strategy on financial decision-making performance and has provided a base from which we can begin to characterize performance episodes.

2.2 How much does emotion regulation influence financial decision-making performance compared with other key factors?

The work undertaken with traders and investors thus far suggests the relevance of emotion regulation on their financial decision-making performance. However the extent to which emotion regulation influences performance as compared to other factors will require further investigation which is expected to be carried out in the in-depth studies.

2.3 Can emotion regulation be improved through training, in ways which improve human performance?

The interviews undertaken with traders identified the ways in which emotions were seen to influence performance and the need for emotion regulation, but also the current ways in which emotion management is undertaken. Traders spoke about the various strategies adopted by them in an attempt to better manage their emotions (for a detailed discussion see Section 3 'Emotion Management- Existing support' in D8-2.1 'Stakeholder requirements'). The strategies included writing down and reflecting on important trades and the decisions taken with regard to the same. This included keeping a track of the ways in which their decisions changes during the course of the trade, the reason behind changing their decision and reflecting on the same in order to determine whether the trade was emotion or rationality driven. Other emotion management methods included determining and exit strategy before entering the trade, anticipatory emotion management etc. Investors were often seen as putting stop losses in pace in order to reduce the impact of emotions on their decisions.

Thus, the initial discussions with traders and investors suggest merit in training and interventions aimed at improving human performance and minimizing the role of non-relevant emotions on financial decision making. We found that experienced traders do report learning more effective emotion regulation over time. This suggests that there may be scope for interventions which target improvements in the emotion regulation of traders and investors.

2.4 Summary

In conclusion, there appears to be merit in investigating the relevance of emotions and emotion regulation for financial decision making of traders and investors. There appears to be not only a recognition of the role of emotions but also a pressing requirement for better emotion regulation and development of interventions that can not only aid healthy emotion management but do this in a manner which suitably fits in with the current learning and work environment. In order to do the same, further in-depth studies with traders and investors need to be carried out. These in-depth studies are expected to employ sensors and economic experiments and the exploratory work undertaken with the same in discussed in the next sections.

3 Exploratory sensors study

Exploratory sensors studies were undertaken with the purpose of assessing the feasibility of using certain sensors devices in a lab or field setting for the in-depth studies stage of the research. The feasibility of using EDA in the current research is explored in this section.

Electrodermal activity (EDA) describes the changes in the electrical properties of the skin. These changes are strongly related to the activation of the sweat glands.

There are two different kinds of sweat glands: apocrine and endocrine. While apocrine sweat glands can only be found in the axilla, areola of the breast and genital area, eccrine sweat glands are distributed all over the body. Apocrine sweat glands are larger than endocrine glands and produce a viscous secretion. Endocrine glands produce a watery secretion.

Millington & Wilkinson (2009) differentiate between 4 different kinds of sweating:

- *Thermal sweating*: responsible for thermoregulation of the body.
- *Emotional sweating*: caused by reactions on psychological / emotional states.
- *Gustatory sweating*: caused by food which is very sour, salty or hot.
- *Apocrine sweating*: caused by apocrine sweat glands which are usually activated due to emotions such as anger or fear.

3.1 Description of the study

For EDA recordings, a small current is passed through a pair of electrodes placed on the surface of the skin. Usually the palm side of the hand is used for measurements because of the high density of active sweat glands. However, this positioning is not suitable for field studies as sensors are perceived as very disturbing and are prone to pressure artifacts during daily work which involves considerable keyboard use. Therefore, alternative positions were evaluated for suitability.

The study consisted of two sub-studies: the first sub-study compared signals recorded at the same time at different electrode positions, while the second sub-study compared signal quality measured at the palm with the laboratory measurement system with signals obtained by Sensewear armband at the upper arm.

3.2 Problems occurring during the study

MentalBioScreen K2 was not used for EDA recordings as it only supports a sampling rate of 1 Hz which is too low to analyze skin conductance responses which usually occur within the frequency range from 0.1 - 2 Hz. According to the Nyquist-Shanon sampling theorem a maximum frequency of 2 Hz requires a minimum sampling frequency of 4 Hz. The main advantage of the MentalBioScreen K2 is that two channels can be recorded at the same time. However, given the limitation of the MentalBioScreen K2, the laboratory measurement system was used instead for the recordings with a sampling rate of 500 Hz. The laboratory measurement system had originally been designed to record different kinds of signals. Therefore, it had to be modified such that six EDA channels could be recorded at the same time. Due to the short period of available time it was not possible to galvanically decouple electrodes. Therefore, skin resistance was measured using one ground electrode for all other electrodes.

3.3 Stimulus presentation

To evoke skin conductance responses, subjects were asked to perform a simple audio task. Subjects were seated in front of the PC. The experiment began only after the instructions had been presented. The experiment consisted of a number of different trials. In every trial, a pair of tones was presented. The subjects were asked to judge within one second whether the low or the high tone came first. Depending on the order, either the right or the left mouse button had to be pressed. For the first sub-study an intertrial interval of 15 seconds was chosen. For the second sub-study we used an intertrial interval of 25 seconds. Presentation of the stimuli was done with FLXlab 2.3.

3.4 First sub-study

The objective of this sub-study was to evaluate different electrode placements in order to find an alternative to the placement on the palm for the field studies.

3.4.1 Outline

For the first part of the study, the following electrode positions were evaluated:

- Palm
- Upper hand
- Forearm
- Upper arm
- Chest
- Forehead

The position at the palm was used as a reference for the other placements. The other positions were chosen such that sensors can be placed without disturbing a person during daily work. For instance, if the forehead turned out to be a good position, electrodes could be integrated into a headband.

Due to the problems described above, a pair of electrodes at each position were not used, a single electrode was used instead. Voltage was measured against a ground electrode placed at the side of the forearm. For electrode placements at the hand / the arm, the non-dominant side was chosen. *Figure 3.1* shows the recording setup for the study.

During the experiment subjects were left alone in the FZI library in order to avoid disturbance by the experimenter.

Three subjects with a mean age of 24.3 (1 male, 2 female) took part in the experiment.

Figure 3.1 – Setup of first sensor sub-study

3.4.2 Results

Due to technical errors, timestamps for subject 01 were not recorded. However, as inter-stimulus interval was always 15 seconds it is still possible to interpret the signal as SCRs occur regularly after 15 seconds.

Subject 03 showed no changes of electrodermal activity at all (see ***Figure 3.2***). This effect is well known in the literature as electrodermal non-responsivity. So called non-responders do not show any EDA reactions to external stimuli. Venables & Mitchell (1996) amount the number of non-responders among healthy adults to up to 25%. This means that up to 25% of EDA data recorded during a study might be useless for further analysis.

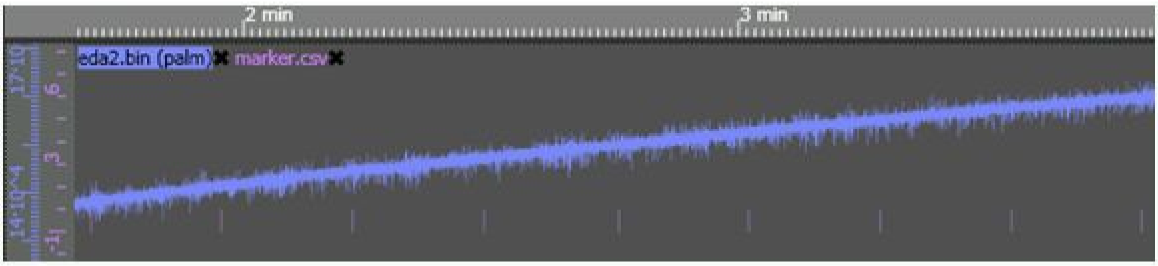

Figure 3.2 – Example for electrodermal non-responsivity (horizontal lines indicate occurrence of audio-stimuli)

The increase of the signal can have different causes. In general, increase of skin resistance (i.e. decrease of skin conductance) can be seen as an indicator of relaxation. However, as the subject stated to feel cold during the experiment, this can also have caused the increase.

Figure 3.3 shows the development of skin resistance of subject 2 during the experiment. At the palm clear responses to the stimuli are visible. However, curve progression also reflects that responses get smaller after a certain number of stimuli. This can be attributed to habituation effects to the stimuli.

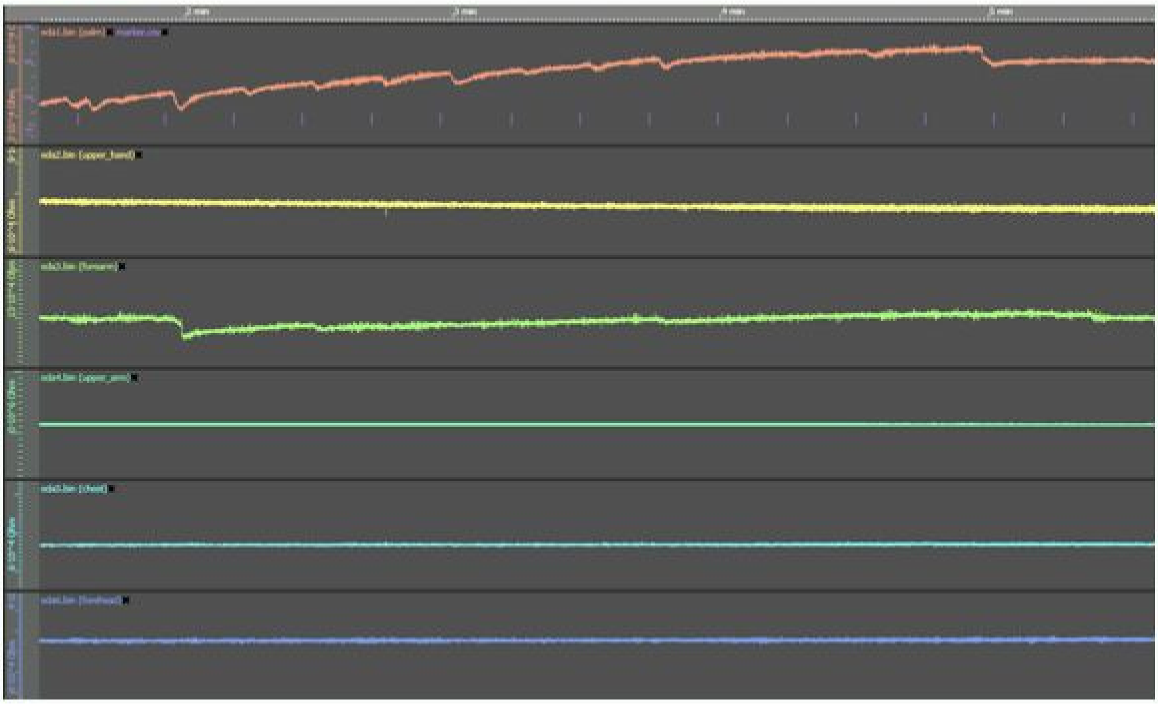

Figure 3.3 – Skin resistance during experiment for subject 02 (horizontal lines indicate occurrence of audio-stimuli)

For some of the stimuli, there are also small responses visible at the forearm. The other positions do not show any reactions to stimuli.

For further analysis, data from the palm was imported to Ledalab (Matlab plugin) and decomposition analyzis was performed to separate overlapping responses. To reduce amount of data, data was downsampled to 20 Hz. Response window (i.e. window in which responses were counted) was set to 1-3 seconds, minimum amplitude to 0.05 uS. After every stimulus at least one response was visible within the response window (2 for event 12 and 16). Moreover, sum of amplitudes of SCRs within response window was computed. *Figure 3.4* illustrates the decrease of amplitudes due to habituation effects.

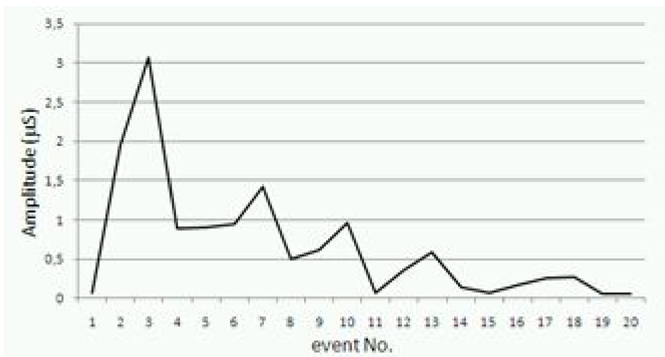

Figure 3.4 – Decrease of amplitude during the experiment

Same analysis was done with the signals recorded at the fore arm. Even when the minimum amplitude was set to 0.01 uS only one SCR after the third stimulus could be counted. The other events did not evoke any responses at the forearm.

3.4.3 Discussion

The results reported above show that best signal quality can be obtained at the palm. This also supports the findings by Rikles & Day (1968) who investigated 15 different positions for electrode placement. They reported that only plantar activity parallel activity at the palm.

Nevertheless, further research should be done with a larger number of subjects to evaluate alternative electrode placements suitable for field studies.

3.5 Second sub-study

This sub-study was conducted in order to compare quality of the EDA signal obtained from Sensewear armband worn at the upper arm with signal quality at the palm recorded by the laboratory measurement system.

3.5.1 Outline

A pair of electrodes was attached at the palm to record EDA with the laboratory measurement system already used in the first part. Moreover, Sensewear armband was worn at the back side of the upper arm. Recordings with the laboratory system were done with a sampling rate of 500 Hz. Sampling rate of Sensewear armband was set to the maximum of 32 Hz.

Again, the experiment took part at the FZI library and the subject was left alone during the experiment.

To evoke SCRs the experimental setup described in 1.1.3 was used with an intertrial interval of 25 seconds. Additionally, an unexpected disturbance was part of the experiment when a person suddenly opened the door, said 'hello' and closed the door again. This was done in order to evoke an even larger response than the ones evoked by the audio stimuli.

The study was done with one female subject at the age of 29.

3.5.2 Results

Figure 3.5 shows the comparison of data recorded with the laboratory system at the palm and the Sensewear armband at the upper arm. '0' marks the timestamp for the audio stimuli. '1' represents the disturbance by opening the door. Please note that upper graph is displayed in Ohm while units of the lower graph are in Siemens (i.e. 1/Ohm).

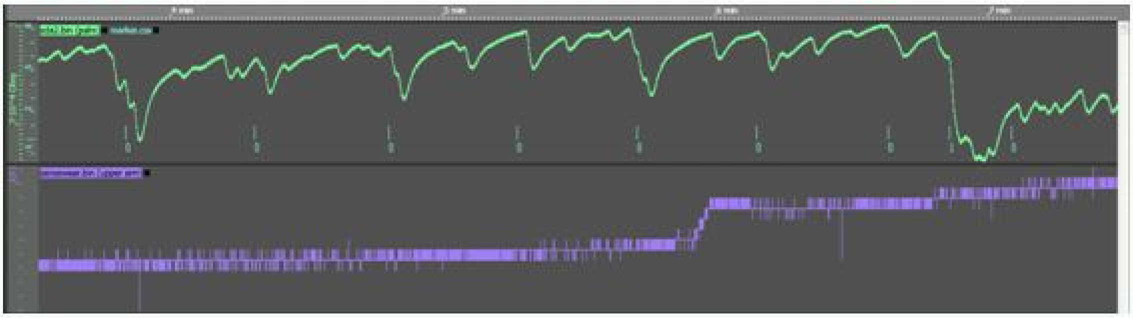

Figure 3.5 – Comparison of EDA recording at the palm and sensewear device at upper arm

Although all stimuli evoke visible responses at the palm, there is no change visible for the sensewear device. Not even the sudden disturbance marked by '1' yields any response at the upper arm although at the palm a drop of skin resistance indicates an activation of the corresponding sweat glands.

However, there is an increase of skin conductivity measured by Sensewear armband around 6 minutes after recording starts. This reaction seems not to be related to one of the stimuli. There are several explanations for this reaction. For instance, it could be caused by environmental conditions or movement of the arm.

3.5.3 Discussion

Analysis of the comparison between signals recorded with the Sensewear armband worn at the upper arm and EDA signals recorded with the laboratory measurement system at the palm of the hand shows that signal quality obtained from the armband is not sufficient for analysis in the field. As results from the first sub-study indicate, there are not even visible responses for the upper arm when laboratory measurement system is used.

Thus overall, it may be concluded that at present EDA suffers from the limitation of having to record signals from the palm of the hand, which restricts its usability in the field. Further testing with traders, discussed in the next section, confirmed it as being deemed an obtrusive method by traders and thus considered unsuitable for use in the field.

3.6 Brief exploratory work with sensors on traders

To get a sense of the extent to which traders are comfortable with the use of sensors and to determine the extent to which certain sensors can be deployed in a field setting, exploratory study using sensors was carried out on traders of one of the participating investment banks.

- The traders did not appear to have any concerns with regard to wearing an ECG device attached to a polar belt.
- Wearing EDA sensors at the palm was regarded as too obtrusive by most of the traders. Given that the best signal quality can be obtained at the palm, the usability of this method in a field setting appears questionable. However, it can still be successfully deployed in a laboratory setting.
- Wearing SOMNOscreen seemed to be no problem. BUT traders only tried the system on for a short period. The first exploratory showed that perception of obtrusiveness of

SOMNOscreen can change after a short period of time (e.g. 20 minutes), thus further testing is required in order to determine the full extent to which this method is fit for deployment in a field setting.

4 Exploratory Economic Experiments

The aim of conducting economic experiments was to investigate the role of emotions and emotion regulation in financial decision tasks. In line with the vision of the project to integrate sensor technology into the development of learning support interventions for financial decision making, sensor technology was tested and integrated into the experimental research. The overarching aim of the exploratory experiments was to approach the question which kind of decision scenarios and data gathering tool should be used for the in-depth studies.

Thus the exploratory experiments tested the applicability of physiological measures for investigating economic decision making. The intention was to learn what the requirements are on the technical side of physiological measurement, as well as the implications of these requirements for experimental design. Different experimental set ups were tested for their potential to be enhanced with physiological measures. The "lessons learned" from these explorations will feed into the design and analysis of experimental and field in-depth studies that integrate sensor technology.

4.1 Exploratory laboratory experiments

Exploratory data was gathered for two different types of economic decision tasks: lotteries and auctions. All experiments were conducted at the Karlsruhe Institute of Technology. Electrocardiogram and electrodermal activity were recorded with a laboratory system that was developed at Karlsruhe Institute of Technology.

4.1.1 Lottery

The first exploratory experiment conducted to test the usability of sensors in an experimental setting was a lottery. The exploratory experiment was conducted with 9 participants. The participants received no monetary incentives for their participation. The participants were asked seven consecutive times to decide between 2 lotteries with different payoff patterns. For example one lottery offered a safe gain of 2 € whereas the alternative lottery offered a 50% chance of winning 6€ and a 50% chance of winning 0€. The choice between the lotteries was made by pressing the buttons 1 or 2 on the computer keyboard.

The decision task consisted of 3 phases:

- Decide-the lottery is presented to the participant
- Input-the participant enters his choice into the keyboard
- Result-the participant learns the results of the lottery

Figure 4.1 shows that the circle of events in the experiment is mirrored in the physiological data. It also reveals that pressing the key on the computer board elicits the largest electrodermal reaction. This finding will be discussed in the "lessons learned" section. Different reactions lotteries with different levels of risk were not observed in the data

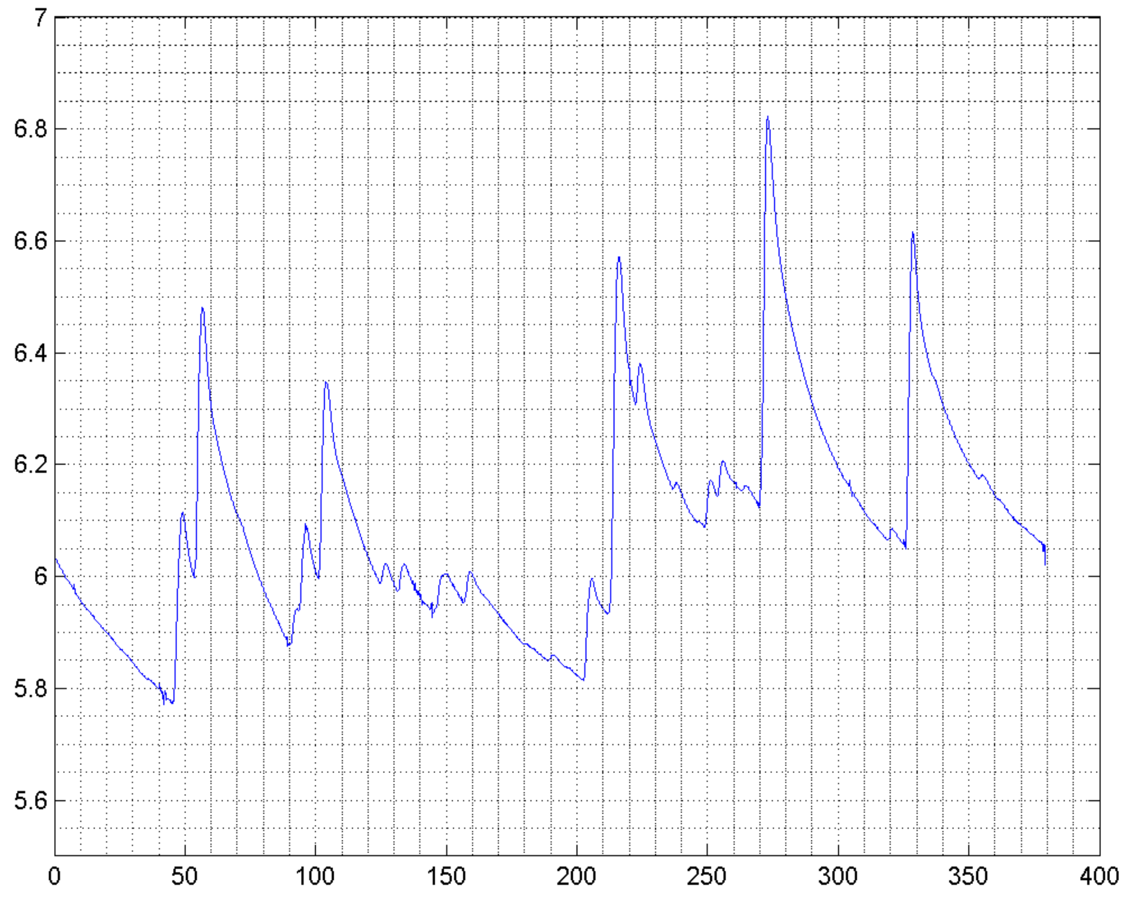

Figure 4.1 – Electrodermal responses to different phases of lotteries over time

4.1.2 Dutch auction

In a Dutch auction the price for the good that is auctioned off decreases in predefined price intervals. The first bidder that accepts the price wins the good for this bid. Participation in a Dutch auction is frequently described as being emotion laden. The lower the price drops the less likely it becomes that the bidder obtains the item, but the bigger becomes her potential payoff if he/she wins. The decision when to accept a price is most likely to be subject to non-rational influences, like nervousness or excitement.

A Dutch auction for two people was conducted in the laboratory. The fictive good that was auctioned off had a common value of 6€. The starting price of the auction was 7€. Every 5 seconds the price decreased in intervals of 0.10€. When a bidder accepts a price he/she earns the difference between the common value of 6€ and his/her accepted price. Participants were fully informed about the rules of the auction. They were paid according to their performance at the end of the experiment.4 sessions were run with 2 players in each session. 3 auctions were played in each session.

The following observations were made.

- skin conductivity rises as the price falls into an area that it becomes interesting to buy (approximately 4.30€).
- There is a huge electrodermal reaction before accepting a price.

- Losers show a huge electrodermal reaction upon losing the auction.

4.1.3 First-price sealed-bid auction

In a first price-sealed-bid auction all bidders submit one secret bid at the same time. Whoever submits the highest bid, wins the auction for his/her bid amount. Previous research has shown that there is a tendency of bidders to place much higher bids, than rational choice theory would predict. Reasons for this phenomenon are still under discussion. One explanation for this behavior is that people are in general risk averse. Recently, emotion based explanations like the anticipated fear of regretting a decision have been taken into account. This is why testing if this auction format is suitable for being enhanced with physiological measures is especially interesting.

In this exploratory experiment one participant made 50 bidding decisions. After each bid he received feedback about the success of his bid and the information what he could have done better. The second feedback information was supposed to elicit feelings of regret. Thus we expected electrodermal reactions at the time of the bidding decision and when the participant receives the two forms of feedback.

An important question was how the participant reacts to the events in the experiment. Moreover we wanted to find out how physiological reactions develop over time, when decision makers have to make a set of repetitive decisions.

The following observations were made:

- the participant showed skin conductance responses to the events in the decision task
- not every event (bid, feedback) elicits a skin conductance response
- the skin conductance amplitudes are higher at the beginning of the decision sequence
- there are less skin conductance responses in the second half of the decision task than in the first half.

The observations show that in an experimental setting physiological reactivity decreases with repetition of the decision task. Possible ways to avoid this effect will be discussed in the "lessons learned" section (section 4.2).

Further exploratory studies have been conducted in the same manner with an English auction and variations of the prisoner's dilemma. An evaluation of the different types of experimental settings leads to the conclusion that measuring physiological signals in auctions yields great potential. Laboratory auctions serve as a simplified model of the mechanism used in stock markets.

4.2 Lessons learned

The lessons learned section summarizes the observations that have been made during the exploratory studies. Each observation is stated and resulting implications for the use of sensors in experimental settings are discussed. Although the exploratory experiments have been conducted in a laboratory setting the "lessons learned" are in many aspects relevant for field research.

4.2.1 Designing field and lab experiments

1. Participants show non-specific skin conductance reactions especially at the beginning of an experiment.

Most participants are excited about taking part in an experiment or study. This excitement is reflected in the physiological data at the beginning of the experiment. If this excitement is not a relevant aspect of the research question participants should be given the opportunity to play practice rounds and to get used to new situation. If possible it is also helpful to arrange a 5 min resting period before the recordings starts.

2. Input into the computer keyboard elicits dominant electrodermal responses.

Interaction with the interface should be reduced to a minimum. Participants should have the possibility to give their answers with minimal movement. They should also be asked to minimize other movements. This includes activities like stretching, scratching and yawning. If a control for these movements is not possible they should be recorded and taken into account as sources of noise when analyzing the data.

3. Sometimes electrodermal reactions overlap.

Stimuli that are relevant for later data analysis should stand alone. There should be enough time between the stimuli that are intended to be analyzed. Otherwise it is difficult to map an electrodermal reaction to a specific stimulus. The stimuli should be at least 15 seconds apart.

4. Electrodermal reactions decrease over time when the decision task is repetitive.

To the best of our knowledge a certain degree of habituation to repetitive tasks and stimuli cannot be avoided. A possibility to create a lasting involvement in the decision task is to set sufficient monetary incentives. Another possibility is to create tasks that are relevant and involving for the decision maker by their own means.

5. Participants react physiologically to distractions.

Every event that is happening besides the task that the participant is working on has the potential to lead to a physiological reaction. This might be the opening or closing of a window or the noise of a ringing phone in the room next door. Even having others move around you can cause physiological reactions that have nothing to do with the task the participant is working on. In a laboratory setting it is therefore necessary to eliminate all possible sources of distraction. Another technique which is also applicable for a field setting is to register all possible sources of distraction that occur during a measurement and to use this protocol to filter artifacts in the data analysis. Of course the sensitivity towards distractions can be an interesting research question.

4.3 Avoiding measurement errors

In the previous section we summarized how the exploratory studies inform design issues of future field and lab studies. Another result of our explorations is a list of possible difficulties that may arise while recording physiological data. Physiological measurements are very sensitive for possible disturbances. Problems can occur because of technical difficulties as well as because of the behavior of participants or characteristics of the experimental setting or task. In the following section possible difficulties are stated and a suggested solution will be discussed.

4.3.1 Technical difficulties

1. Electromagnetic radiation.

The omnipresence of different types of cables in a laboratory setting is responsible for a 50Hz noise that is often observed in physiological recordings. Because the frequency of this noise is known it can be filtered in a post-hoc analysis with digital filters. Still theses signals sometimes interfere with the signals one intends to analyze.

A bigger problem for physiological measurement are unspecific radiations from mobile phones, computers etc. This noise is also very likely to occur in field measurements that take place in settings with a lot of technical equipment (like a trading floor). To avoid these kind of influences the measurement system should be kept away from sources of electromagnetic radiation.

2. Incorrect attachment of electrodes.

A careful application of the electrodes is a key factor of success for recording physiological signals. It is important to place them at the dedicated places on the body. It is also important to use enough gel. The entire electrode needs to be filled with the electrode gel and no air bubbles should occur. Too much gel on the other hand keeps the electrodes from sticking to the body and results in bad signals. Thus the right amount of gel has to be applied. This can be achieved by practicing the process a couple of times with an expert.

3. Low amplifier battery.

Even when the amplifier is off the battery slowly looses power. Thus the battery needs to be charged on a frequent basis.

4.3.2 Other sources of difficulties

1. Movement of participants.

The movement of participants is most problematic for the interpretation of physiological data. Every movement is reflected in the physiological recordings. To avoid these kinds of physiological reactions that are not intended by the experimental set up, participants need to be asked to sit very still and relaxed while performing the relevant task. Even the clicking of the computer mouse has consistently shown to cause EDA reactions. Thus every input into the experimental software needs to be conducted with as little movement as possible.

2. Non-specific responses.

In accordance with literature our exploratory studies have shown that sometime changes in physiological parameters occur, without an obvious eliciting stimulus. These non-specific responses sometimes make it difficult to establish a causal link between stimuli and physiological reaction.

3. Non-responders.

Another phenomenon that has been described in the literature that also occurred in our studies is that of non-responders. Especially women sometimes do not show any electrodermal reactions. People that are classified as "non-responders" cannot participate in studies in which electrodermal activity is supposed to be analyzed.

4.4 Conclusion

The exploratory experiments have shown that measuring physiological responses in the context of financial decision making is a promising method. Auctions deliver very suitable decision characteristics to investigate the link between emotions, physiology and decision making. Their set up can be adjusted to the specific requirements of physiological measures and they offer the possibility to extract the core decision situation and all the relevant events that are important for the formation of the decision. Still there are a lot of aspects that need to be considered when recording physiological measures in laboratory and field settings.

All aspects of physiological measurement and experimental set up that resulted from these exploratory studies will be a valuable source of information for the design and analysis of in-depth studies. The lessons learned from theses exploratory experiments will help to avoid technical mistakes as well as flaws in designing future laboratory experiments and field studies that involve physiological data collection.

5 Implications of exploratory studies for in-depth studies

The relevance of emotions and emotion regulation for the financial decision-making performance of both traders and investors has been well discussed in section 2 of this document. Thus in addition to literature reviewed, the exploratory studies undertaken with traders, their managers and investors suggest that many believe effective emotion regulation to be important to effective trading performance. Experimental laboratory based investigations of decision-making behaviour have many advantages. For example, they provide the ability to control for potentially confounding variables. They provide ideal conditions for monitoring physiological signals. However findings from laboratory studies with naïve subjects do not necessarily translate into the behavior of expert performers in real world performance domains (Todd & Gigerenzer, 2007). Thus the in depth studies seek to employ both experimental and field studies. Thus we can examine detailed causal hypotheses in controlled laboratory conditions while also examining whether the effects of emotion regulation on decision-making performance hold for the case of real world trading by investors and professional financial traders. The in-depth studies to be carried out draw on early results of interviews and ethnographic research carried out with traders, their managers and investors; as well the exploratory studies on sensors and economic experiments.

Key implications of these exploratory studies for further include:-

- The relationship between emotion and decision-making needs to understood as a dynamic relationship which unfolds over time and in which emotions play multiple roles.
- As well as testing key hypotheses about the link between emotion regulation and financial behaviour, we need to produce a rich description of the interaction of emotion, emotion regulation, deciding and acting over performance episodes.
- We are building sufficient confidence in the viability of emotion regulation approaches to improving financial decision-making that it is reasonable to commence work on exploring game based approaches to improving human performance via improved emotion regulation.
- ECG provides the most robust physiological signals for field investigations. This is helpful since heart rate captures the interaction of sympathetic and parasympathetic nervous systems and thus via analysis of heart rate variability can provide a physiological measure of emotion regulation.
- Both ECG and electro-dermal response can provide useful signals for laboratory experiments subject to the cautions and procedures outlined above.

6 Appendix A – References

Todd, P. M. & Gigerenzer, G. (2007). Environments that make us smart: Ecological rationality. *Current Directions in Psychological Science, 16*(3), 167-171.