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Spring 5-29-2015

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USING LIVE BIOFEEDBACK FOR DECISION SUPPORT: INVESTIGATING INFLUENCES OF EMOTION REGULATION IN FINANCIAL DECISION MAKING

Research in Progress

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Abstract

The influence of emotions on decision making is widely accepted, however, research investigating emotions within decision support systems is scarce. Previous research showed that via emotion regulation decision makers can significantly improve their decisions. However, a sound perception of emotions is a foundation for beneficial emotion regulation. In this paper, we propose the use of live biofeedback–the provision of real-time information about a person's current physiological state–as a potential feature for decision support systems in online environments. We developed a research model and hypothesize that live biofeedback can moderate (i) the influence of the decision environment on decision makers' physiological states and (ii) the decision makers' perceptions of their emotional states. Within the current research a live biofeedback prototype for decision support in the context of financial trading was implemented. We aim at testing the hypothesized moderating effects of the developed decision support system in the controlled environment of a laboratory market experiment.

Keywords: Live Biofeedback, Decision Support, NeuroIS, Emotion, Emotion Regulation.

1 Introduction

While traditional theories on human decision making assumed that our decisions are completely based on analytical reasoning, our guts may always have suspected that there is more to human decision processes than cognition alone. Meanwhile the relevance of emotions for decision behaviour is widely accepted and supported by empirical evidence (Lerner and Keltner, 2000; Sanfey et al., 2003). Especially in the context of financial markets, where environmental elements such as competition and time pressure are common influences, emotions substantially effect decisions and therefore should be considered (Adam et al., 2015; Fenton-O'Creevy et al., 2011; Ku et al., 2005; Lo et al., 2005; Shiv et al., 2005). For example, it was shown that financial traders who are able to identify and distinguish among their current emotions achieve a higher decision making performance (Seo and Barrett, 2007).

Building on Dimoka et al. (2012), who outlined research opportunities of online decision aids using physiological measurements, we propose live biofeedback (LBF) as a complementary feature for decision support systems (DSS). Based on neuroscience methods and tools (e.g. electrocardiogram, electromyography, or electrodermal activity measurements), LBF is a promising approach for providing decision makers with information about their physiological states (Dimoka et al., 2012; Loos et al., 2010; Riedl et al., 2014; vom Brocke et al., 2013). LBF can be integrated in DSS and thus support decision makers' abilities to monitor, evaluate, and modify their emotional reactions, which is referred to as emotion regulation (Thompson, 1994). Emotion regulation strategies can help decision makers to improve the effects of their emotions on decision making. In our research model, we hypothesize that the information provided through LBF can impact decision making by (i) influencing the physiological state of the decision makers and (ii) increasing the decision makers' perceptions of their physiological states. To test the hypothesized moderating effects of the developed LBF DSS on the perceived emotions and the physiological states, the LBF prototype will be investigated within a controlled laboratory experiment in the context of financial markets.

The remainder of this paper is organized as follows: Section 2 presents the theoretical background of this work. Firstly, the term LBF is explained and the need for LBF in DSS is outlined. Subsequently, we conceptualize the influence of emotions and emotion regulation on decision making in our research model, and derive hypotheses regarding the moderating impact of LBF on physiological states and perceived emotions in the context of financial decision making. To test these hypotheses within a realistic use-case, we integrated an LBF feature into a DSS that supports financial trading. The LBF DSS is investigated in a controlled laboratory experiment, which is described in Section 3. Finally, in Section 4, we discuss limitations, present conclusions, and outline our future work.

2 Theoretical Background

2.1 Live Biofeedback as a Complementary Feature for Decision Support

Various types of feedback mechanisms are already state-of-the-art in modern DSS. For example, DSS can provide decision makers with feedback about their past decision performance. When decision support is provided by an interactive optimization tool, decision makers might also receive feedback about those areas of the search space, they are particularly interested in (Köksalan and Karahan, 2010). A further example are group DSS, where feedback about opinions or decision processes of other group members is provided to the decision maker (Sengupta and Te'eni, 1993; Vetschera, 1991). In the current research, we propose LBF, a complementary feedback type for DSS, which provides decision makers with information about their physiological states.

LBF refers to the relationship between a person's physiological state and the perceived emotions (Al Osman et al., 2013). Green et al. (1969, pp. 33–34) defined a psychophysiological principle, which states that "[e]very change in the physiological state is accompanied by an appropriate change in the mental-emotional state, conscious or unconscious, and conversely, every change in the mental-emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state." This physiological principle describes the interplay between body and mind: our physiological state has an effect on our mental state, which, in turn, via emotion regulation, can influence our physiology. However, a high coherence of the perceived emotions and the actual physiological state is necessary for learning and applying emotion regulation strategies. Since precise emotion perception is a difficult task, Al Osman et al. (2013) suggested LBF to support accurate perception of emotions.

The term biofeedback was initially introduced in 1969, when the first annual meeting of the "Association for Applied Psychophysiology and Biofeedback" was created (Association for Applied Psychophysiology and Biofeedback, 2014). Research about biofeedback "[…] comprises the design, development, and testing of smart and precise instruments that measure physiological activities […] and generate an appropriate feedback response" (Al Osman et al., 2013, p. 3145). The physiological activities mentioned in this definition can be any measurable body signal (also referred to as biosignals) such as heart activity, eye movements, skin temperature, or brain activity. Biofeedback can be applied to support the management of physiological processes (Al Osman et al., 2013; Loos et al., 2010). The provision of biofeedback in *real-time* is referred to as LBF.

LBF is based on neuroscience tools and can be applied to support humans to gain awareness of their physiological states (Dimoka et al., 2011; Nacke et al., 2011). The concept of LBF is applied in various domains–e.g. in serious games and in learning environments (Astor et al., 2013; Mandryk et al., 2013) or as stress management support for office workers (Al Osman et al., 2013; Ouwerkerk et al., 2013). LBF might furthermore be utilized to train emotion regulation skills and thus to influence physiological states (Al Osman et al., 2013; Jerčić et al., 2012). These two effects of LBF, the impact on the physiological state as well as increased coherence of the physiological state and the perceived emotions, could contribute to DSS as a complementary feature by supporting emotion regulation and thus improving the impact of emotions on our decision making (Astor et al., 2013).

2.2 The Influence of Emotions and Emotion Regulation on Decision Making

The research model presented in Figure 1 captures our understanding of the moderating impact of LBF on the decision makers' physiological states and perceived emotions as well as the influences of the decision environment, the physiological states, and the perceived emotions on the decision. The decision environment comprises factors that affect decision making (Payne et al., 1993). Within classical decision theory the maximization of utility determined the choice (Dyer et al., 1992). We included the described influence of the decision environment on decision making into our research model by introducing *relation A*, where the decision environment includes the decision maker's utility function as well as the applied strategy and contextual factors.

In the past, non-utility related elements of the decision environment, such as time pressure or the influence of stakeholders (Payne et al., 1993), were hardly considered in decision theory (Elster, 1998; Loewenstein, 2000; Peters et al., 2006). However, these aspects may trigger emotions, which are a fundamental part of our lives (Lopes et al., 2004; Sütterlin et al., 2013). Empirical evidence showed that emotions have a significant impact on decision making (Adam et al., 2015; Fenton-O'Creevy et al., 2003; Ku et al., 2005; Walla and Panksepp, 2013; Zajonc, 1980). Emotions involve changes of physiological states (Gross and Thompson, 2007; Mauss et al., 2005). For example, elements of the decision environment, such as time pressure or the presence of competitors, can lead to emotional arousal, which manifests in an increase of heart rate and skin conductance (Adam et al., 2012; Teubner et al., 2015; Zhang et al., 2012). Therefore, by introducing *relation B*, our research model considers the influence of the decision environment on the physiological state.

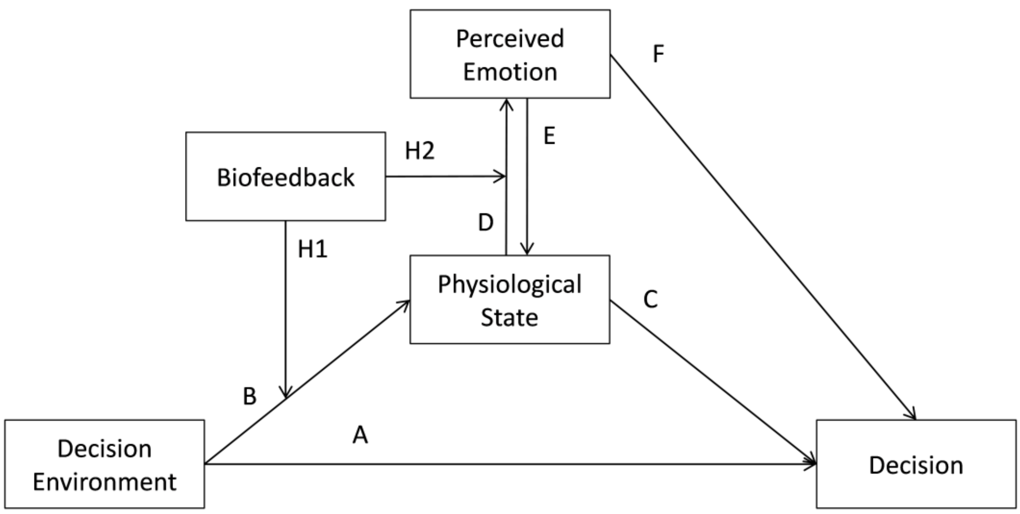

Figure 1. Research model.

Physiological states are "[…] strong enough to change behavior" (Winkielman and Berridge, 2004, p. 121). This influence of physiological states occurs beyond conscious awareness and is referred to as "unconscious emotion" (Winkielman and Berridge, 2004) or "affective information processing" (Walla and Panksepp, 2013). Existing empirical evidence shows that judgements (Winkielman and Berridge, 2004) or affective discriminations (i.e. "like-dislike" ratings) (Zajonc, 1980) are influenced by physiological states beyond participants' cognitive awareness. We included the impact of physiological states on decision making in the research model by introducing *relation C*.

Of course, not all emotions are unconscious. The coherence of the perceived emotions and the actual physiological state, however, is difficult and highly dependent on the abilities of the individual decision maker (Feldman Barrett et al., 2001) – some people have poor access to their physiology (Pennebaker, 2000), whereas others are better in perceiving their body's physiological processes. For instance, Sze et al. (2010) investigated the coherence of perceived emotions and cardiac activity. The authors found that subjects who are experienced in Vipassana meditation have a higher coherence of perceived emotion and physiological state than experienced dancers (with attention to somatic sensations), which again have a higher coherence than a control group without meditation or dance experience. Our research model comprises the influence of the physiological state on the perceived emotions within *relation D*.

A closer investigation of the relation between emotions and emotion regulation by Fenton-O'Creevy et al. (2011) showed that not only emotions are crucial for decision making, but also the decision maker's emotion regulation strategies. In literature the five emotion regulation families "situation selection", "situation modification", "attentional deployment", "cognitive change", and "response modulation" introduced by Gross (1998) are well established. It has been shown that emotion and emotion regulation are inextricably interwoven and different emotion regulation strategies have different impacts on (i) the physiological state and (ii) the actual decision (Fenton-O'Creevy et al., 2011). The first of the mentioned impacts of emotion regulation effects the modification of physiological states (Thompson, 1994). Thereby the modification of physiological states can mean subduction, inhibition, maintenance, or even enhancement of emotional arousal (Masters et al., 1991). The research model includes the modification of the physiological state based on the perceived emotions in *relation E*. The second impact of emotion regulation relates to the influence of the perceived emotions on decision making. This influence can be observed in multiple dimensions: they distort information that are retrieved and memorized by decision makers (Bower, 1981; Mayer et al., 1990), alter risk-taking attitudes (Hariharan et al., 2014; Lerner and Keltner, 2001; Lo and Repin, 2002; Shiv et al., 2005), and effect decision makers' valuations of the decision outcome (Gray, 1999). Empirical evidence even indicates that some emotion regulation strategies (e.g. reappraisal) influence decision performance positively (Astor et al., 2013; Heilman et al., 2010; Lo et al., 2005; Lo and Repin, 2002; Seo and Barrett, 2007). The influence of the perceived emotions, comprising emotion regulation strategies, on the decision is introduced into our research model by *relation F*.

In summary, decision environment, physiological state, and perceived emotion are acknowledged elements that are known to influence the decision. These elements as well as their influences on each other (i.e. relations A–F) are well established and thus build the foundation of our research model.

2.3 Research Hypotheses: Moderating Effects of Live Biofeedback

In order to enhance decision making through the application of the desired emotion regulation strategies, decision makers need to accurately perceive and process their emotional states (Damasio, 2005; Feldman Barrett et al., 2001). However, the perception of the emotional state is a difficult task that depends on the decision maker's individual abilities (Feldman Barrett et al., 2001). Due to the significance of emotions in the decision making process (Virlics, 2013), we propose to support emotion regulation by integrating information about the decision maker's emotional state into DSS.

Measuring a person's emotional state is considered one of the most complex problems in affective science (Mauss and Robinson, 2009). Three approaches to measure emotions are established: (i) subjective measures (e.g. questionnaires), (ii) behavioural measures (e.g. the measurement of facial behavior (Ekman and Friesen, 1978)), and (iii) physiological measures (e.g. skin conductance, heart rate, or pulse). These approaches can be seen as complementary methods to acquire information about the emotional state. The current research builds on recent developments in NeuroIS and focuses specifically on physiological measures, as a foundation of LBF (Adam et al., 2011; Dimoka et al., 2012; Loos et al., 2010; Riedl et al., 2014; vom Brocke et al., 2013). Based on physiological measures, the decision makers' emotional states can be derived and provided as valuable information within DSS (vom Brocke et al., 2013). A benefit of measuring emotions through physiological measures is that they allow to acquire information that are not—or only to a limited extent—influenced deliberately (Soler, 1990). Additionally, observing emotions via biosignals is not bound to the decision makers' perceived emotions and therefore can acquire information beyond the decision makers' awareness (Cacioppo et al., 2007; Schaaff and Adam, 2013). Furthermore biosignals are measurable in a continuous and unobtrusive manner and thus allow emotions to be measured at their time of occurrence and without interrupting decision makers from performing their tasks (Schaaff and Adam, 2013). The latter aspect is crucial for a DSS feature that provides real-time information.

Due to these aspects, we propose the use of LBF as a complementary feature for DSS. In particular, we expect that the integration of LBF into DSS can support decision makers through two specific pathways, which are reflected in our research hypotheses. First, we believe that LBF moderates the influence of the decision environment on the physiologic state (D). LBF may, beyond the decision maker's awareness, influence the impact of the decision environment on physiologic state, because its mere existence emphasises the importance of emotions. This assumption is in line with the findings of Jerčić et al. (2012, p. 12), who found that emotion regulation can be trained in a serious game with LBF, even though in a fast-paced environment the "[…] participants paid little or no attention on the arousal meter indicator during the whole playing session." Second, we expect that the application of LBF results in higher coherence of the perceived emotions with the actual physiological state (E). These assumptions are reflected in the following hypotheses H1 and H2:

- **Hypothesis H1.** Live biofeedback moderates the effect of the decision environment on the physiological state.
- **Hypothesis H2.** Live biofeedback moderates the influence of the physiological state on the perceived emotion, resulting in an increased coherence of the perceived emotions and the physiological states.

LBF opens up new possibilities to study and contribute to long term emotion regulation skill development (Astor et al., 2013), leading to an advanced emotional processing, which, according to Bechara and Damasio (2005), is necessary to make sound economic decisions. Recent literature (Loewenstein et al., 2001; Rick and Loewenstein, 2008) claims that the emotions experienced during the decision making process should be involved in decision making theory. Building on this development, we suggest to use neuroscience tools like physiological measures to gain a deeper understanding of the moderating influence of LBF on the interplay between emotions, emotion regulation, and financial decision making (Dimoka et al., 2012; Gimpel et al., 2013; Riedl et al., 2014; vom Brocke et al., 2013).

3 Experimental Evaluation

3.1 Experimental Setting: Live Biofeedback for Financial Decision Making

As part of the current research, we developed a DSS that includes a LBF feature. To test our research hypotheses (H1, H2) in a controlled laboratory environment, we used the LBF DSS in a financial market experiment. We argue that our financial market experiment is particularly suited for investigating LBF in the context of DSS for several reasons. First, the presence of competitors, which is a common characteristic of financial markets, leads to increased emotional arousal. Second, financial markets usually represent fast-paced decision environments that resolve in increased emotional arousal (Ku et al., 2005). This effect is even intensified through the presence of computerized algorithmic trading, also referred to as high-frequency trading (Hendershott and Riordan, 2013). Third, it should be considered that DSS are already well established in the domain of financial markets (Keen, 1987; Sanders and Courtney, 1985). Finally, financial decisions can be considered as “important decisions” and thus predestined for powerful emotions (Loewenstein, 2000; Lucey and Dowling, 2005). We therefore propose to test a prototype for LBF as a complementary feature for DSS in the context of financial decision making, as financial decisions are known to be fuelled by emotions triggered through competition and time pressure (Ackert et al., 2003; Lo and Repin, 2002; Zhang et al., 2012).

In detail, regarding the experimental setting for testing our DSS, we chose a double auction (DA) mechanism for the trading of common value (CV) assets, since securities on financial markets generally imply a CV character (Dow and Gorton, 1997). The DA mechanism forms the basis of many financial markets such as stock exchanges (Madhavan, 1992) and thus has been a topic of high interest in the fields of financial as well as computational and experimental economics in the last decades (Das et al., 2001; De Luca and Cliff, 2010; Hendershott et al., 2011; Hendershott and Riordan, 2013; Zhang et al., 2012). As large proportions of today’s trading activity occur in a human and computer populated trading context (Hendershott and Riordan, 2013; Zhang et al., 2012), we also integrated computerized agents into the experimental context. Not only does the presence of computer traders make our setting more realistic, but it may also influence the decision makers’ physiological state (Zhang et al., 2012). In summary, based on the work of Bloomfield et al. (2009) and Zhang et al. (2012), we designed a financial market scenario to test the LBF feature for DSS within a realistic use-case.

In accordance with Bloomfield et al. (2009), we created a financial market setting for security trading. On each market exactly one security is traded within a trading period of 120 seconds. Each security yields in a predetermined liquidating dividend according to its true CV. Six trader types can interact in a market: human informed, human uninformed, and human liquidity traders as described by Bloomfield et al. (2009), but also computerized versions of those traders. Informed traders receive a private clue about the true liquidating dividend of the traded security at the beginning of each period, resulting in imperfect information for each single trader, but also in the possibility of discovering the true value of a security by information aggregation. Uninformed and liquidity traders receive no additional information about the true liquidating value of a security. They obtain only the commonly known information that the distribution of the dividends is bell-shaped. Liquidity traders additionally receive a target for buying or selling a certain number of securities. At the beginning of each security trading period each trader has a zero cash and a zero share endowment, but with the possibility of unlimited negative balances for cash and shares. In this setting, the market outcome in terms of both, individual performance measures and informational efficiency, can be measured.

3.2 Implementation of Live Biofeedback Decision Support in a Financial Market Experiment

We implemented the described DSS, including a LBF feature for decision support, as well as the experimental settings, in Java. The trading interface with the LBF feature is depicted in Figure 2. The LBF feature was implemented in the form of an arousal meter (see the interface element within the red rectangle in Figure 2). The arousal meter displays the decision maker’s arousal levels based on their current physiological states on a scale from 0 to 100. The scale consists of coloured bars, which change from green to red as the level of arousal increases. The LBF value itself presents the decision maker’s current level of arousal, which is based on the amplitude of the skin conductance signal in a five second time interval in order to fulfil the real-time requirement (Healey and Picard, 1998).

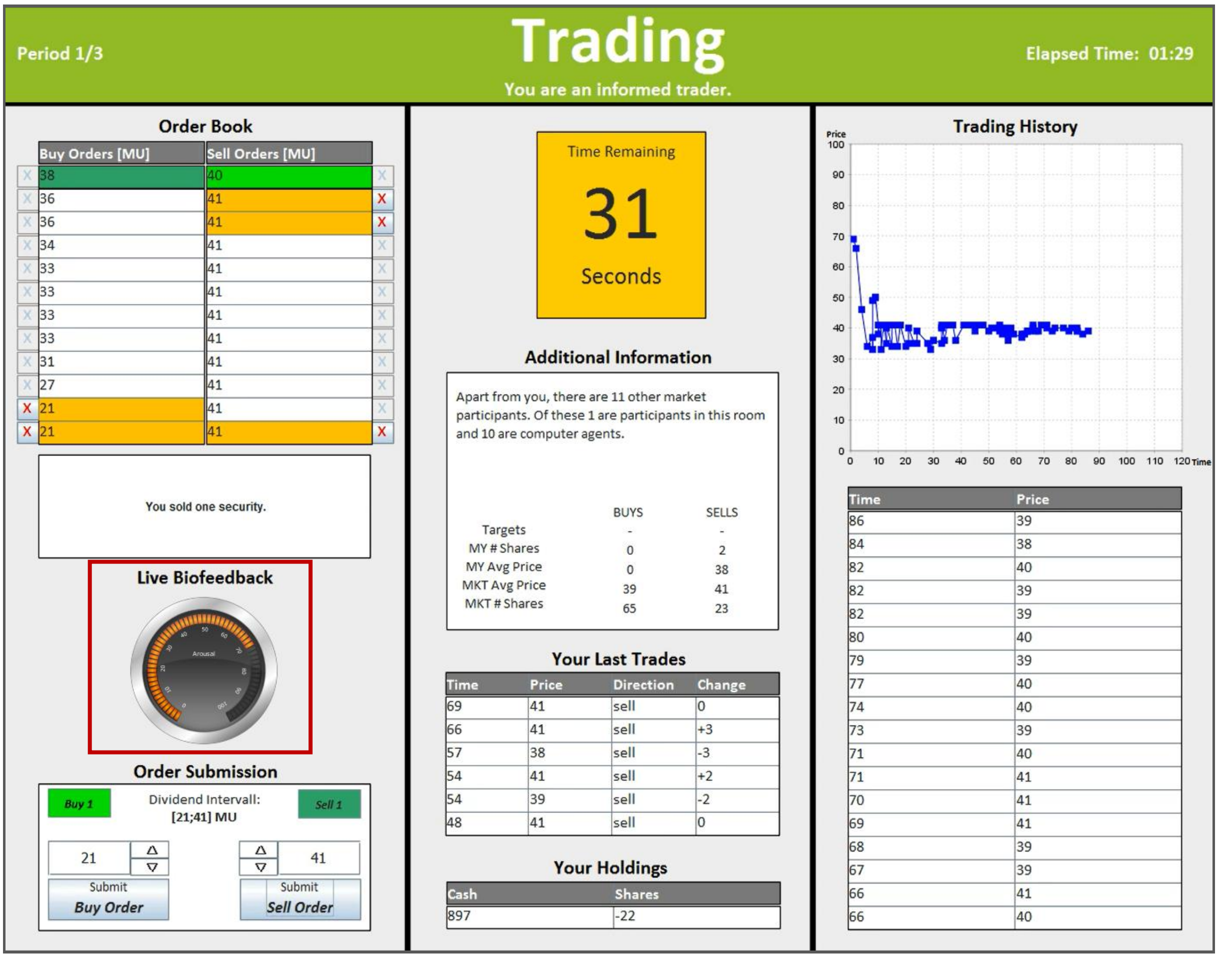

Figure 2. Trading interface with arousal-meter live biofeedback.

Within our experimental design, the level of arousal induced by the decision environment (low Arousal/high Arousal) and the LBF feature (with LBF/without LBF) serve as treatment variables resulting in a 2 (Arousal) x 2 (LBF) factorial design. Thus, we will compare observations with and without the LBF DSS with respect to low and high arousal levels. We plan on increasing (decreasing) the level of arousal that is induced by the decision environment by increasing (decreasing) time pressure based on shorter (longer) sleep/wake cycles of the computer traders. Based on the described 2 x 2 factorial design of our experiment, the hypothesized moderating effects of the LBF feature (H1, H2) can be evaluated in a financial setting. In order to test whether LBF moderates the influence of the decision environment on the physiological state (H1), the physiological states of the participants in the treatments with and without the LBF feature in a low and high arousing decision environment can be compared. Furthermore we intend to test the moderating effect of LBF regarding the influence of the physiological state on emotion perception (H2). Therefore the coherence of the perceived emotions with the physiological states will be assessed by comparing participants' self-reports with physiologic measurements acquired during the experiment. The self-reports will be based on the Positive and Negative Affect Schedule (PANAS) and the Emotion Regulation Questionnaire (ERQ)—established measures of emotion (Gross and John, 2003; Watson et al., 1988). Similar to Jerčić et al. (2012), we will evaluate the use of the LBF feature by the decision makers through self-report, but also through eye-tracking. In this way, we can investigate the relation between the time the decision makers look at the LBF feature and their state of coherence.

4 Conclusions and Future Work

In this paper, we proposed LBF as a possible feature of DSS. We emphasized the role of emotions and emotion regulation on decision making. Contemporary research shows that emotion regulation can be beneficial for decision making. Since emotion perception is a difficult task and highly dependent on the abilities of the individual decision maker, we suggest the use of LBF for decision support. Based on a literature review we designed a research model that comprises the effects of the decision environment, the physiological state, and the decision maker's perceived emotions on the decision. We introduced LBF and hypothesized its moderating effects on the physiological state and the perceived emotions.

In order to test the relevance of LBF as a possible feature for DSS, we designed and implemented a DSS prototype within a financial market setting. This setting includes multiple human as well as computer traders. Based on physiological measurements, the trading decisions, and questionnaires, we intend to analyse the four presented experimental treatments. The experiment will be executed in a controlled laboratory environment with up to 12 human participants trading on the same market per session and several sessions per treatment. We expect that LBF has two moderating effects. First, we believe that LBF influences the impact of the decision environment on the decision makers' physiological states beyond their awareness. We expect the influence of the decision environment on the physiological state of the participants in the LBF treatment to be less intense and thus the participants' arousal levels to be lower overall than of those without LBF. Second, we assume that the coherence between the perceived emotions and the physiological state will increase with LBF. Overall, we are confident that LBF can be beneficial for decision making and thus should be considered as a feature for DSS. In our future work, we therefore aim both (i) at evaluating our research model for varying decision making environments and (ii) at analysing whether LBF is indeed beneficial for decision makers due to improved emotion regulation.

In future research, the LBF feature itself could be investigated in greater detail. For example, we need to test which skin conductance parameter, such as amplitude or rise time of the skin conductance signal (Boucsein, 2012), even other physiological parameters (e.g. parameters based on heart rate) are applicable best for measuring a person's physiological state in real-time. Also, breaking LBF features down to their characteristic elements (e.g. the type of display or the underlying biofeedback parameter), could help to get a deeper understanding of how LBF can be used to enhance DSS.

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