MEASURING EMOTIONS IN ELECTRONIC MARKETS

Completed Research Paper

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Abstract

Although the importance of emotions in economic decision-making is being widely accepted, it is still unclear how and to what extent emotional processing affects economic behavior. In this paper, we propose a new methodological framework for behavioral IS studies that we call physioeconomics, by which it is possible to measure psychophysiological correlates of human emotions during controlled laboratory experiments. In contrast to brain imaging technologies as in NeuroIS, the analysis of autonomic physiological parameters can be achieved with a comparatively low amount of measurement overhead and, thus, allows collecting empirical data for much larger sample sizes. Therefore, this approach is particularly qualified for the study of emotions in electronic markets. In order to show that physioeconomics is able to provide insightful results we apply this method in an exemplary auction experiment in which we compare bidders' arousal throughout the bidding process and in response to winning or losing.

Keywords: Auctions, Electronic markets, Emotions, Experiments, Physioeconomics

Introduction

How do emotions affect human decision-making behavior and how can the study of emotions help the architects of Information Systems to better understand decisions of human individuals? In his forecast on the future of economics, Thaler (2000, p. 139) claimed that the well-known and perfectly rational "homo economicus will become more emotional," indicating that economists will devote more attention to the study of emotions and include emotional factors in their models of decision-making. While economic theory provides a highly elaborate methodology for analyzing organizational behavior and complex macroeconomic interrelations, economic models, though highly sophisticated and rich, often fail to capture the complexity of individual (human) decision-making. Economic models tend to understand decision-making as a single rational maximization of expected utility, rather than as a dynamic process involving both cognitive reasoning and emotional processing. Camerer (2003, p. 1673) argued that "most economic theories minimize the influence of human emotions" and Sanfey et al. (2003, p. 1755) even claimed that such models "idealize the decision-maker as a perfectly rational cognitive machine." We claim that human decision-making is both a cognitive and an affective *process* rather than a single, indivisible maximization of utility.

In this paper, we propose a new approach for behavioral IS studies that can enhance our understanding of the dynamic decision-making process of human individuals. In particular, we propose to consider and measure emotion-related physiological data, such as skin conductance or heart rate, when conducting economic laboratory experiments. In this article we provide a framework for an appropriate adaptation of these psychophysiological parameters into behavioral experiments, over and beyond the collection of other observables, like data on economic behavior and self-report measures. Furthermore, we provide evidence from the application of this framework that it can in fact contribute to a better understanding of human decision-making in IS research.

In presenting this new method, which we call *physioeconomics*, we focus on the application domain of electronic markets. Although the application of physioeconomics is not limited to electronic markets, there are several reasons to highlight the usefulness of this new approach in this context. First, electronic markets, and especially Internet auctions, are considered to be "one of the greatest success stories of web-based services" (Ariely and Simonson, 2003, p. 113) and are therefore highly relevant to IS research. Second, previous theoretical and empirical research suggests that emotions play an important role in this domain (e.g. Engelbrecht-Wiggans, 1989; Ku et al., 2005). Third, in order to study (electronic) markets, it is necessary to consider the interdependent decisions of many (if not all) market participants simultaneously. This distinguishes the application feasibility of physioeconomics from neuroeconomics. The measurement of psychophysiological autonomic variables can readily be achieved through wearable devices and, thus, allows to study the emotions of many economic subjects at the same time; not only in the lab, but possibly also in the field.

The remainder of this article is structured as follows. In Section 2 we introduce the methodology of psychophysiology and evaluate physiological parameters for their adequate use in economic studies. Section 3 provides an overview on related economic experiments in the laboratory and the field that have applied physiological measurements. Section 4 discusses a methodological framework for the execution of physioeconomics in controlled laboratory experiments. In Section 5 we present and discuss the results of a physioeconomic experiment, in which we actually measure physiological responses in an electronic auction. Finally, Section 6 concludes.

Measuring Emotions

Experimental economics is a well-established methodology for investigating behavior in markets (Roth, 2002). The methodology of experimental economics provides experimenters with a standardized procedure to analyze economic decision-making of human individuals in a controlled laboratory environment (Kagel and Roth, 1995; Guala, 2005). Thereby, it is a complementary approach to economic theory, as it allows to systematically analyze the predictions of economic models in a controlled environment. As proposed by Smith (1976, 1982), an economic experiment comprises a standardized economic environment, on which the experimenter establishes a controlled microeconomic institution. The microeconomic institution comprises a set of rules, which describe how subjects can interact with each other and how their individual payoffs are computed. Consequently, the trading rules of an (electronic) market constitute such a microeconomic institution. The rules of a market describe when and how bidders can place their bids, who obtains the commodity for sale, and how much each bidder has to pay. Together, the standardized economic environment and the microeconomic institution define a microeconomic system (Smith, 1982). Over the past decades, economic laboratory experiments have proven to be an insightful source of research, complementing empirical studies (Falk and Heckman, 2009). Most importantly, the methodology of experimental economics allows to observe *real* human behavior in a controlled environment. Thus, Falk and Heckman (2009, p. 536) concluded: "Behavior in the laboratory is reliable and real - participants in the lab are human beings who perceive their behavior as relevant, experience real emotions, and take decisions with real economic consequences."

Physioeconomics builds on this well-established methodology of experimental economics, but additionally incorporates physiological measurements of participants as proxies for their individual emotional processing. It starts from the intuition that decision-making is both a cognitive and affective process rather than a single, indivisible maximization of utility. On the one hand, this dynamic process comprises strategic considerations of the agents concerning the maximization of their expected payoff. These aspects are the main focus of game theory today and are fairly well understood. On the other hand, however, there is an inevitable influence of affective or emotional factors that also have an impact on the decision-making process (Elster, 1998; Loewenstein, 2000). In the context of Internet auctions for example, Ding et al. (2005) argue that emotions are an inherent component of a bidder's decision-making. One phenomenon that is frequently observed in traditional and Internet auctions, and that is associated with increased emotionality, is *auction fever* (e.g. Johns and Zaichkowsky, 2003; Ehrhart et al., 2008). Under auction fever, bidder's "adrenaline starts to rush, their emotions block their ability to think clearly, and they end up bidding more than they ever envisioned" (Murnighan, 2002, p. 63).

While experimental economics provides a highly reliable and sophisticated methodology for analyzing economic behavior in the laboratory, research in psychophysiology focuses on the complex interrelationship of physiological states, perceptual, cognitive, or emotional processes, and human behavior. In this paper, we suggest that the appropriate adaptation of psychophysiological parameters (e.g. skin conductance and heart rate) to traditional methods of experimental economics can contribute to a better understanding of human decision-making in electronic markets and IS in general. In contrast to the mere use of questionnaires and interviews, which often have to deal with the problem of subjectivity and social-desirability bias, the analysis of physiological parameters offers the intriguing opportunity to complementary examine objective parameters that show robust correlations to emotional processes of human agents. In contrast to the field of neuroeconomics, or NeuroIS (Dimoka et al., 2010), we focus here on the activation of the autonomic nervous system (ANS) only, as this system's status can be assessed with a comparatively low amount of measurement overhead and, thus, putting the focus on the ANS allows for collecting empirical data in much larger samples.

In the field of NeuroIS, neuroimaging techniques (e.g. functional magnetic resonance imaging) are used to measure vascular changes in different anatomical brain regions. These hemodynamic responses are regarded as a proxy of neuronal activity in response to external stimuli (e.g. market events) and they are frequently interpreted as resulting from cognitive or emotional processing (e.g., Sanfey et al., 2003). However, since no brain region exclusively subserves isolated aspects of information processing, such interpretations always represent inferences based on previous knowledge. Importantly, emotional processing has historically not been directly linked to regionally specific brain activity but instead to the ANS (James, 1884). Thus, changes in the ANS accompanying affective states have been thought to represent a core feature of emotional experience and are, thus, regarded as an important descriptive dimension in the majority of psychological theories of emotion. Therefore, a measurement of autonomic physiological activity might serve as a more direct proxy of emotional processing and thus provides important insights into the affective modulation of human decision-making beyond NeuroIS.

Moreover, the measurement and analysis of autonomic physiological responses is much less complex and considerably cheaper as compared to neuroimaging data. For example, a 3 Tesla magnetic resonance imaging system that can be used for NeuroIS research costs approximately 3,500,000 USD and one hour scanning time is typically estimated at about 140 USD. By contrast, a system for measuring skin conductance and heart rate costs less than 7.000 USD and single-use electrodes are available for a few US cents. Additionally the measurement devices are wearable and can possibly be used in controlled field experiments. Because of these differences, physioeconomic experiments can be conducted in a variety of settings that do not allow for conducting NeuroIS research. These conditions concern, for example, the analysis of emotional processing in the strategic interaction of many subjects in a market environment or the collection of data on emotional processing during real applications in the field (Fenton-O'Creevy et al. 2010).

Taken together, we think of physioeconomics as a complementary line of research in addition to NeuroIS that allows for estimating different aspects of emotional processing in a variety of conditions that cannot be covered by NeuroIS technologies.

Emotions, Feelings, and Somatic States

In order to measure emotions in electronic markets, it is crucial to properly define what emotions and feelings actually are, as these terms are often used interchangeably in the literature. Unfortunately, elaborating a general definition of the term emotion turns out to be a complex task, which can lead to the impression that there "seem to be as many definitions as investigators" (Bradley, 2000). As a matter of fact, an immense body of psychological literature defines, depending on the particular context, emotions and feelings from various perspectives (Panksepp, 1982; Ortony and Turner, 1990). Reflecting a rather general understanding of emotions in psychological literature, one can roughly define the term emotion as a subjectively experienced state that can be described qualitatively and is accompanied by changes in feeling, physiology, and expression. Thus, a subjectively experienced feeling is only a part of the broader concept of emotion, which also comprises objectively observable changes, e.g. in physiology. As described by Rick and Loewenstein (2008), emotions can be further distinguished into immediate emotions, anticipatory emotions, and the ongoing current emotional state.

This paper concentrates specifically on the physiological aspects of emotions. Therefore, it follows a more psychophysiological perspective and also takes into account the definitions of Bechara and Damasio (2005). Psychophysiology is both a psychological, as well as a physiological discipline and, therefore, an interdisciplinary field of research. Based on the assumption that human perception, thought, emotion, and action are embodied and embedded phenomena (Cacioppo et al., 2007a), its major focus is to gain a profound understanding of the dynamic interaction of human behavior, physiological processes, and perceived feelings. Bechara and Damasio (2005, p. 339) defined an emotion as "a collection of changes in the body and brain states triggered by a dedicated brain system [...] relative to a particular object or event." Thereby, the authors focused in particular on the physiological aspects of emotions. The specific object or event which can cause an emotion is defined as an *emotionally competent stimulus*. In the context of electronic markets, market events, such as the start or the end of an auction or the event of being outbidden by another participant represent such stimuli (Adam et al., 2011). In contrast to the physiological term emotion, Bechara and Damasio (2005, p. 339) defined a feeling as a rather psychological construct: "The ensemble of signals as mapped in somatosensory regions of the brain itself provide the essential ingredients for what is ultimately perceived as a feeling, a phenomenon perceptible to the individual in whom they are enacted." Finally, the emotion caused by the stimulus triggers responses to the body that are enacted in a somatic state involving physiological modifications. These modifications, which also contribute to the psychological aspect of emotional experience, comprise changes in a number of parameters related to the ANS (e.g., heart rate and skin conductivity). In the following, some of these physiological parameters typically used in psychophysiology will be discussed and evaluated for their use in experiments on electronic markets.

Physiological Parameters

A large body of psychophysiological research on emotions relies on the interpretation of measures that reflect the activity of the ANS. The ANS normally acts outside conscious awareness and, therefore, cannot be directly influenced by free will (Cacioppo et al., 2007b). It is necessary to adjust visceral functions to match environmental demands. The ANS can be roughly partitioned into the sympathetic and the parasympathetic (vagal) nervous system that typically function in opposition to each other. The sympathetic nervous system activates the organism for *fight or flight*, while the parasympathetic nervous system promotes digestion and recreation. Although both branches of the ANS typically have antagonistic effects on a number of internal organs, they seem to be regulated rather independently (Berntson et al., 1991). Thus, the whole system acts in functional synergy and sympathetic as well as parasympathetic activity can be modulated by adjusting environmental conditions.

Skin conductance is one of the most frequently used measures in psychophysiological research. It reflects sympathetic activity and corresponds to the electrical conductivity of the human skin, which in turn is driven by sudomotor activity of eccrine sweat glands. The density of these glands is highest at palmar and plantar sites and it is therefore recommended to use these areas for measurement (Fowles et al., 1981). The skin conductance signal can be decomposed into tonic and phasic components with the former reflecting the general arousal level of the examinee (skin conductance level, SCL), i.e. the ongoing current emotional state, and the latter representing short bursts of sympathetic activity (Wallin, 1981), which are usually elicited by an external or internal stimulation (Boucsein, 1992; Dawson et al., 2007), i.e. immediate or anticipated emotions. These monophasic skin conductance responses (SCR) typically occur 1 to 3 seconds after a discrete event, but they can also be observed in absence of an identifiable stimulus (non-specific SCR). Especially the amplitude of SCRs, commonly denoted as SCR.amp, seems to be a valid index of personal significance and arousal (Lang et al., 1993). Thus, biologically relevant stimuli such as the own name typically elicit larger SCRs than irrelevant information (Ben-Shakhar et al., 1975).

The cardiovascular system has also been in the central focus of psychophysiological research during the last decades (Jennings et al., 1981). It comprises the heart and the vasculature which distributes the blood to all tissues of the body. The electric activity of the heart can be easily measured by means of an electrocardiogram (ECG). For a number of psychological research questions, it is sufficient to quantify heart rate by measuring the time between successive R-waves in the ECG (Jennings et al., 1981). This measure is modulated by both, the sympathetic and parasympathetic branch of the autonomic nervous system. However, the vagal system exerts a much wider range of control over cardiac chronotropy and it responds faster to external events (Berntson et al., 2007). Similar to the electrodermal activity, heart rate can either be averaged across longer periods of time to reflect tonic arousal, or changes in heart rate following discrete events can be quantified by measuring slight variations in successive heart periods (Velden and Wölk, 1987). This latter phasic measure was shown to be correlated with the valence of external events. Thus, negative events typically elicit a heart rate decrease whereas positive events are more likely to be accompanied by heart rate accelerations (Bault et al., 2008; Lang et al., 1993). Again, tonic emotional processing refers to a subject's ongoing current emotional state, while phasic responses relate to immediate and anticipated emotions.

Evaluation for Experiments on Electronic Markets

The physiological parameters discussed so far particularly allow for identifying two dimensions of emotional processing: arousal and valence (Lang et al., 1993). Thus, the skin conductance level and the amplitude of skin conductance responses are sensitive indexes for the general level of arousal and the degree of arousal associated with a single stimulus, respectively. Phasic heart rate, on the other hand, allows for evaluating the perceived valence of a certain stimulus with negative stimuli typically eliciting deceleratory responses and positive stimuli relative heart rate accelerations.

We propose to particularly focus on skin conductance and heart rate changes in market experiments for three reasons. First, these measures allow for the simultaneous assessment of arousal and valence of emotional processing. Second, these physiological changes occur in the very moment of human information processing and decision-making and, thus, allow for objectively measuring emotional responses without requiring a subjective evaluation of the participant. Third, it is possible to utilize such physiological responses in decision-making comprising strategic interaction of two or more participants. Particularly markets inherently comprise decisions in strategic interaction of at least two individuals. With a clear experimental structure and complementary questionnaires, the perceived feelings, e.g. joy or anger, associated with a single emotion can be further isolated. Especially with respect to the third issue, it becomes clear that the approach of physioeconomics provides an essential extension to the field of NeuroIS that only allows for measuring changes of brain activity to external events in one examinee at a time. Thus, NeuroIS approaches either have to restrict these measurements to one specific individual during strategic interactions or they even have to use experimental setups where the actions of other participants (e.g. bidders in the same auction) are only simulated by a computer algorithm (e.g. Delgado et al., 2008). These NeuroIS procedures severely narrow the examination of human decision-making in electronic markets and we therefore propose to extend this research by using measures of autonomic activity to improve the analysis of emotional processing in such situations.

Psychophysiological Measurements in Economics

The measurement of skin conductivity and heart rate are a well-established methodology in psychophysiology. However, the application of this method for the investigation of economic research questions is fairly new. Previous research can be roughly categorized in studies that consider emotions during economic decision-making (1) without strategic interaction, (2) with strategic interaction between two individuals, and (3) with strategic interaction in markets (i.e. between three or more individuals).

Among the most influential physioeconomic experiments without strategic interaction is the *Iowa gambling task* by Bechara et al. (1997). In this sequential choice task, subjects are given the choice between two lotteries with different, but unknown, expected payoffs. After playing some rounds, subjects usually develop a strategy to prefer lotteries with advantageous outcomes. Interestingly, at a very early point in time, SCR amplitudes signal the quality of decisions with higher amplitudes being elicited by less advantageous decisions. This bodily signal seems to occur before participants are able to explicitly describe their decision strategy. Summing up these results, Bechara et al. (2005) proposed in their famous *somatic marker hypothesis* that advantageous decision-making is only possible in consequence of a prior accurate emotional processing. Therefore, emotions are beneficial for decision-making if they are integral to the task, but may be disruptive if they are unrelated to the task. Several subsequent experiments find additional support this hypothesis (e.g. Crone et al., 2004; Werner et al., 2009) and indicate that SCRs systematically vary with the outcome of a choice even before feedback is given (Bechara et al., 1997; Biermann et al., 2005). Thus, autonomic responses reliably correlate with the quality of economic decisions even in the absence of explicit knowledge of these decision properties.

Economic experiments that apply physiological parameters in the context of strategic interactions with two individuals are often based on the existence of decision asymmetries between the two players, such as in the power-to-take game (Bosman and van Winden, 2002) or the ultimatum game (Güth et al., 1982). In both games, the first decider can determine how a given amount of money should be split up between the two parties and the second decider can accept or reject the distribution offer, or propose a new distribution. If the responder rejects, or proposes a new distribution, respectively all or some of the payoffs are forfeited for both parties. Ben-Shakhar et al. (2007) analyzed the power-to-take game and reported that those responders who had a stronger increase in arousal measured by SCL destroyed larger amounts of their initial endowment. Van't Wout et al. (2006) analyzed the responders' SCRs upon receiving offers in the ultimatum game and reported higher SCRs for unfair offers in comparison to fair offers. The authors defined unfair offers as offers in which the amount of money is unequally split between the proposer and the responder. When playing against a computer counterpart though, this pattern of emotional response could not be observed. Additionally, van't Wout et al. (2006) showed that higher SCR amplitudes are associated with higher rejection rates, which again is not the case when facing a computer counterpart. The emotional arousal observed by van't Wout et al. (2006) is very similar to the activation pattern of a brain region referred to as *anterior insula* as reported in a neuroeconomic experiment by Sanfey et al. (2003). This correlation between physiological arousal and economic behavior fits to the above mentioned link between somatic states and decision-making (Bechara and Damasio, 2005) and indicates that emotions can serve as a sensitive predictor of economic behavior.

To the best of our knowledge, only four previous studies have taken physiological measurements into account in a market context. The first study in this series is a controlled field experiment by Lo and Repin, (2002), who measured physiological parameters of professional security traders during live trading sessions. A large variety of physiological parameters is subject of their analysis: skin conductance, finger pulse amplitudes, heart rate, electromyographical signals, respiration, and body temperature. The authors analyzed the impact of market events, e.g. changes in the spread or the volatility, on the physiological parameters recorded. In their results, Lo and Repin (2002) reported significant physiological responses to various market events. This indicates that the decision-making process of financial traders seems to be accompanied by emotions. Most interestingly, the authors found that physiological responses to market events depend on the expertise of the trader, i.e. senior traders show a different pattern of emotional arousal than junior traders.

Smith and Dickhaut (2005) analyzed the impact of different auction mechanisms on the arousal of market participants. In particular, they compared bidders' average heart rate during participation in a sequence of Dutch and English auctions, respectively. The authors concluded that the English auction, as a collection of all relevant stimuli, induces less emotional arousal than the Dutch auction. However, the authors did not address which specific features of the Dutch auction are in fact responsible for the reported increased emotionality. To this end, Adam et al. (2008) analyzed skin conductance and heart rate of bidders during common value Dutch auctions. The authors found that Dutch auction participants have a significantly higher degree of arousal once the standing price has reached a certain level. Adam et al. saw this as support of their conjecture that the Dutch auction generates a thrill of excitement which tempts bidders to underbid their preselected bidding limit. Finally, Astor et al. (2011) investigated the influence of different feedback information in response to winning or losing a first-price sealed-bid auction. The authors showed that the *loser regret information*, i.e. being informed about the amount of money a losing bidder could have achieved, induces stronger SCR amplitudes than the respective *winner regret information*, i.e. being informed about the amount of money a winning bidder left on the table.

In summary, these studies showed that emotions play a significant role for economic decision-making and that physiological measurements of emotional correlates are inevitably linked to these decisions. According to the somatic market hypothesis of Bechara and Damasio (2005), one can even argue that a correct emotional processing is a prerequisite for sound economic decisions. However, to date no standardized methodological procedure for conducting controlled economic experiments with physiological measurements has been proposed. The studies that have been referenced here have been conducted by researchers from the fields of psychology, medicine, or economics, each of which has different standards for such experiments. For example, in psychology subjects are often deceived by the experimenter and paid a lump-sum-fee for participation (e.g. Bault et al., 2008). In contrast, such practice is not accepted in economics (cf. Smith, 1976, 1982). In order to guarantee reliable and replicable results, it is essential to establish a standardized framework for the execution of physioeconomic experiments. We propose such a framework in the next section.

Methodological Implications

According to Nobel laureate Vernon Smith "control is the essence of experimental methodology" (Smith, 1976, p. 275). More specifically, control is the ingredient that ensures replicable and reliable results of the experimental methodology. It can only be achieved through a standardized economic and experimental environment (Smith, 1982). The amendment of economic laboratory experiments by physiological measurements imposes a variety of methodological implications for the experimental environment, in particular for the session structure and the environmental conditions. In the following, these methodological implications are discussed while proposing a session framework for the execution of physioeconomic experiments.

Implications for the Session Structure

We summarize the methodological implications for the session structure in a session framework, which is depicted in Figure 1. In experimental economics, a *session* is defined as a "group of trials conducted on the same day and the same set of subjects," with a *trial* being "an indivisible unit of observation" (Friedman and Sunder, 1994, p. 212). A *period* is defined as a "self-contained unit of time for observation, e.g., a single auction." Our proposed session framework comprises four phases: (A) a *preparation phase*, (B) a *decision-making phase*, (C) a *perception phase*, and (D) a *rest phase*. The following subsections each focus on one phase of the framework.

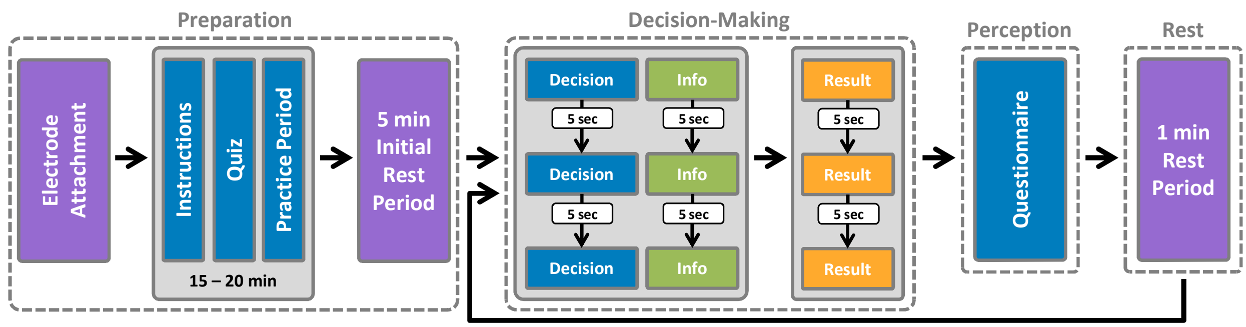

Figure 1. Session Framework

(A) Preparation Phase

The first phase of a session is used for preparation. This phase comprises the electrode attachment, the reading of participant instructions, a quiz regarding the participant instructions, a practice period, and an initial rest period.

Electrode Attachment. The placement and attachment of the measurement electrodes should follow a standardized routine (Boucsein, 1992; Gramann and Schandry, 2009). Such a standardized routine does not only enhance the signal quality, but also ensures a similar treatment for all participants. The problem of signal quality is less serious for ECG measurement, as such measurement comprises a comparatively low signal amplification. To the contrary, signal amplification is much higher for skin conductance measurement. To prepare the skin for measurement, Gramann and Schandry (2009) recommended to wash hands with warm water without soap. The soap can cause maceration of the skin, which in turn leads to a decrease of overall skin conductivity (Boucsein, 1992). This can drastically distort skin conductance values if some subjects wash their hands with soap and others do not.

Instructions and Quiz. Some authors argue that physiological measurements cannot be conducted right after the measurement electrodes were attached to the participants (Boucsein, 1992; Schmidt and Walach, 2000). For instance, it is not guaranteed that the electrode paste used for SC measurement exactly matches the skin's ion concentration (Schmidt and Walach, 2000). Therefore, Boucsein (1992) recommended attaching the electrodes about 15 to 20 minutes before the beginning of measurement. Gramann and Schandry (2009) argued that this waiting time is particularly important if the temperature difference between the laboratory and the external environment is comparatively large. However, it is important to note that this procedure is by far not applied in all psychophysiological experiments. In order to efficiently utilize time while conducting the actual experiment, it seems sensible to use the recommended waiting time of 15 to 20 minutes to read aloud the participants instructions and let the subjects participate in a short comprehension quiz regarding the instructions. A comprehension quiz is common practice in experimental economics and contributes to ensure that the subjects understand the rules of the respective microeconomic institution (Guala, 2005).

Practice Period. In general, autonomic measures are very sensitive to novelty and bodily movements (Dawson et al., 2007). In order to reduce the impact of novelty, it is very important to introduce the decision-making situation to participants before actually measuring physiological parameters. This can either be achieved by a practice period in the beginning, in which gains and losses are not considered, or by removing the first few decision periods from the data set. As an additional benefit, introducing a practice decision period also contributes to an increased comprehension regarding the rules of the experiment. Whether a practice round should be introduced or rather the first few rounds be cut off depends on the *focus* of the experimental design. In particular, wealth effects, strategic inferences, and learning effects can play an important role (Thaler and Johnson, 1990; Guala, 2005).

Initial Rest Period. As physiological parameters tend to have a high degree of inter-subject variability, it is important to introduce an initial rest period prior to the actual economic decision-making and, thus, control for an individual basic level of physiological arousal. For at least two reasons, it seems sensible to explicitly inform participants that this rest period is necessary for calibrating the physiological measurement for each participant. First, it is an important paradigm of experimental economics to provide subjects a trusted environment that is enriched with information (Guala, 2005). Second, subjects can then conclusively be asked to use this rest period to relax. This is particularly important, because cognitive tasks can have substantial effects on the physiological parameters and can, therefore, distort the baseline assessment. Usually, an initial rest period of *5 minutes* is used in psychophysiological literature (Vossel and Zimmer, 1990; Schmidt and Walach, 2000; Sütterlin et al, 2011). The individually assessed basic level of arousal can then be used in order to reference the level of arousal during economic decision-making, e.g. the tonic SCL and heart rate (see the experiment in the next section).

(B) Decision-Making Phase

After the preparation phase, participants take part in a first period of market decision-making. A period of decision-making is followed by either another period of decision-making, a perception period, or a rest period. Depending on the focus of investigation, decisions as well as information and results are displayed in timed intervals. In order to reduce the impact of bodily movements on the physiological parameters, user interaction with the experimental software has to be minimized. In particular, keyboard inputs should be avoided wherever possible and replaced with simple mouse inputs. Vossel and Zimmer (1998) recommended to provide participants with a soft pad for their non-dominant hand to further reduce bodily movements and measurement artifacts. The amount of information displayed to subjects has to be minimized as well. We propose to display results, e.g. prices and payoffs, and other information, which is subject of investigation, in timed intervals of at least 5 seconds (cp. Sanfey et al., 2003; Astor et al., 2011). By doing that, the experimenter allows for identifying the stimulus responsible for a single physiological response. This would not be possible if all information was presented simultaneously or in too short intervals of time.

(C) Perception

Physiological measurements allow for identifying a subject's general level of arousal, as well as the intensity of single emotional responses and, to a certain extent, the valence of emotional processing. However, they do not allow to further specify which feelings a subject ultimately perceives. In order to identify specific feelings, e.g. joy and anger, the experimenter can control the set of possible feelings by a sophisticated experimental design and successive revelation of information (e.g. Bault et al., 2008; Adam et al., 2011). For instance, specific information provided to bidders can induce winner and loser regret in auctions (Engelbrecht-Wiggans and Katok, 2008; Astor et al., 2011). Furthermore, the physiological measurements can be enriched with complementary questionnaires. Such questionnaires can be conducted (1) after each period of decision-making or (2) after all periods of decision-making have finished. Thereby, it is important to note that a perception questionnaire in between two periods of economic decision-making can also have an impact on the behavior of the subjects and their emotional processing. Research in psychology provides several standardized questionnaires to (subjectively) identify specific feelings and their intensity. Prominent examples of such questionnaires are the *affect grid* (Russel et al., 1989) and the *self-assessment-manikin* (SAM) (Bradley and Lang, 1994). Furthermore, the experimenter can design own questionnaires, which specifically focus on his or her individual experiment. However, it is important to recall that questionnaires always have to deal with subjectivity and social desirability bias.

(D) Rest Phase

If a change of the subject's (tonic) current emotional state during decision-making is focus of the investigation, each period of economic decision-making should be followed by a rest period of at least 1 minute. This rest period is necessary in order to evaluate the degree of physiological arousal during one single decision-making period, because it allows the physiological parameters to return to an individual baseline of arousal.

Implications for the Control of Environmental Conditions

The measurement of physiological parameters and their interpretation strongly require to monitor and control environmental conditions, i.e. room temperature, relative humidity, and background noise. In general, these environmental conditions should be kept as constant as possible (Dawson et al., 2007).

Temperature and Relative Humidity. Boucsein (1992) recommended to keep temperature in the thermoneutral zone of 25-26° C (77-78.8° F). Schmidt and Walach (2000) reported a use of 23-24° C (73.4-75.2° F) in psychophysiological experiments, while Vossel and Zimmer (1998) recommended a temperature between 21 and 23° C (69.8-73.4° F). For relative humidity, both Schmidt and Walach (2000) as well as Vossel and Zimmer (1998) recommended to ensure a level of 45-55%. Further, even seasonal changes (Venables and Mitchell, 1996) and the time of day (Hot et al., 1999) can significantly influence SC measurement. Therefore, we propose to conduct physioeconomic experiments within a period of 2-3 weeks, control for the time of day throughout the different treatments, keep a temperature of approximately 23° C (73.4° F) and a relative humidity of approximately 50% throughout all sessions. These environmental conditions should also be reported along with the experimental results.

Background Noise. Background noise during the experiment should be avoided, as any perceived noise can potentially cause a physiological response (Berntson et al., 2007; Dawson et al., 2007). Further, even the sound of mouse-clicks elicited by other participants of the experiment can cause a physiological as well as a behavioral response. As a matter of fact, we observed a change in behavior during trial auction experiments when subjects could hear the mouse-clicks of other participants. In particular, when one group placed a bid (by clicking a button on the screen), the subjects of the other group heard the mouse-clicks and placed a bid within milliseconds, too. This behavior could not be observed when subjects were equipped with ear-muffs. However, this problem does usually not arise in psychophysiological or NeuroIS experiments so far, as these studies typically only measure one subject at a time, while the strategic interaction analyzed in physioeconomic experiments inherently imposes simultaneous measurement of at least two subjects. Further, if subjects can hear mouse-clicks of other participants, their decision-making turns from simultaneous to quasi-simultaneous. This imposes another problem, as Abele and Ehrhart (2005) have shown that participants behave economically different when deciding simultaneously or only quasi-simultaneously. Therefore, in order to avoid the problems of measurement artifacts and changes in economic decision-making, subjects of physioeconomic experiments should be equipped with ear-muffs or seated in separated soundproof cabins.

An Application of the Physioeconomic Method in Market Experiments

In this section, we present and discuss a physioeconomic market experiment that was conducted according to the previously derived framework. This experiment can be thought of as an exemplary study utilizing physiological measures to reveal affective processes in an electronic market environment. In particular, we investigate subjects' arousal and emotions while participating in a descending price auction. In this type of auction an initial high standing price is consecutively decreased by a decrement after fixed time intervals until one of the bidders claims the good by accepting the current standing price (McAfee and McMillan, 1987). In the literature, this auction format is usually referred to as *Dutch auction* (Carare and Rothkopf, 2005; Wolfstetter, 1996). Dutch auctions have a long standing history in practice and in academic literature (Cassady, 1967) and are also used in Internet consumer auctions, e.g. on the platforms *1-2-3.tv* and *sevensnap.com*.

From a physioeconomic perspective, Dutch auctions are especially interesting because they have a 'click-to-win' characteristic, i.e. the first auction participant that 'clicks' will win the item at sale, while all others lose. This is believed to especially fuel bidders' excitement (Stafford and Stern, 2002); a conjecture which we can test with the physioeconomic method. Moreover, we chose Dutch auctions for our application of physioeconomics, because there is an unresolved academic dispute on why the observed final prices in the Dutch auction are significantly lower than in the strategically equivalent first-price-sealed-bid (FPSB) auction. Following the revenue equivalence theorem of Vickrey (1961), these two auctions should actually yield the same final prices. One explanation for this phenomenon is that the real-time characteristic of Dutch auctions gives market participants an additional "utility of suspense" that is not present in the FPSB auction. Cox et al. (1982, p. 27) came to this conclusion, because in their seminal experiments on the Dutch auction "many subjects report that they enjoy the 'clock experiment' more than the others because of the 'suspense of waiting.'" In conclusion, the authors conjectured that each bidder *i* may derive an additional non-monetary utility $a_i(t) \geq 0$ from participating in a Dutch auction of length *t*. In order to prolong the experience of their utility of suspense, so the authors further, participants place bids later in the Dutch auction, and thus below the price level of the FPSB auction. In an attempt to verify this hypothesis in a follow-up experiment, Cox (1983) assumed, according to the above formal representation, that the utility of suspense is only driven by the length of the Dutch auction and independent of a bidder's expected monetary payoff. However, they found that final prices are also dependent of bidders' expected monetary payoff and, therefore, discarded the utility of suspense hypothesis. In our physioeconomic experiment, we will show that the bidders' level of excitement directly depends on the expected monetary payoff and may, thus, be in line with the existence of a utility of suspense.

Experimental Design

In our experiment, each bidder takes part in a series of 15 Dutch auctions. In all auctions, the auctioneer starts the auction at an initial high price of 120 monetary units (MU) and then consecutively decreases the current standing price by 1 MU every 5 seconds. 6 participants are invited for a single experimental session. In a random stranger matching (Kagel and Roth, 1995), participants are randomly reassigned to two groups with three bidders each before every single auction period. Each group independently plays a single Dutch auction with three bidders each, i.e. there are three bidders in each single auction. An auction has finished as soon as one of the three bidders accepts the current standing price. The winning bidder receives the resale value for the commodity and has to pay the price at which he or she accepted to finish the auction. In the experiment, the bidders each receive an independent private value (IPV), i.e. an individual valuation for the artificial auctioned off commodity (see e.g. Cox et al., 1982; Katok and Kwasnica, 2008 for similar approaches). This IPV is independently drawn, for each subject, from a uniform distribution with support on the discrete integer interval {21, 22, ..., 119, 120} MU. The bidders only know their own IPV and the general distribution of IPVs.

Table 1. Value Classes

Value Class	Value Interval	
HIGH	88 MU	120 MU
MEDIUM	54 MU	87 MU
LOW	21 MU	53 MU
Total Range	21 MU	120 MU

For the analysis, the bidders' randomly drawn IPVs are categorized into three different value classes: *LOW*, *MEDIUM*, and *HIGH*. As listed in Table 1, the three value classes segment the range of the value distribution into three intervals of almost equal size. With these value classes, we can conduct a within-subject comparison of arousal regarding the expected payoff in an auction. By applying Bayes' rule, the bidders can derive a probability function of having been induced with the highest IPV in the auction (Vickrey, 1961). If the bidders' individual bidding functions are symmetric and monotonically increasing in a bidder's IPV, the probability of having the highest valuation is also the probability of winning the auction. The two main research questions for our experiment are the following: First, we investigate whether a bidder's degree of physiological arousal is affected by the randomly drawn IPV. In other words, contrary to the conjecture of Cox et al. (1983), we hypothesize that the bidders' excitement (utility of suspense) depends on their expected payoff in the Dutch auction. Second, with respect to the observation of Stafford and Stern (2002, p. 44) that bidders perceive auctions as a "play-to-win game," we test which of the two possible emotions in response to the end of the auction is experienced stronger: the joy of winning or the frustration of losing.

Procedure

The experiment followed the session framework we proposed in the last section and was conducted at the Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany. The experimental system was implemented using the z-Tree environment for economic experiments (Fischbacher, 2007). The interactions with the experimental system were limited to mouse inputs and subjects were equipped with ear-muffs to avoid susceptibility to background noise. Altogether 5 female and 19 male subjects (24 in total, mean age = 22.73 years) participated in 4 sessions. The subjects were randomly recruited from a pool of undergraduate students with an academic background in economics. Before the experiment started, the participants were endowed with a lump sum payment of €15.00. The experimental currency was set to monetary units (MU) with 1 MU being equivalent to €0.20. Depending on their individual performance, the bidders accumulated all gains and losses during the auctions on their own accounts. These accounts were paid out in cash at the end of the experiment. The average payment was €29.06, with €21.40 and €36.00 being the minimum and maximum payments, respectively. During the whole experiment, participants' skin conductivity was recorded with a constant current amplifier measurement system and Ag/AgCl (silver/silver chloride) electrodes. The electrodes were attached on the thenar and hypothenar eminences of the palm of the non-dominant hand by use of standard EDA electrode paste (Boucsein, 1992). Heart rate was derived from an ECG recording using a two-lead method with single-use electrodes placed on the left and right wrist. All sessions were conducted within a period of two weeks with an average room temperature and relative humidity of 23.55 °C (74.39 °F) and 46.80%, respectively. The skin conductance measurement results of 5 subjects had to be removed from the data sample, because their values were outside the range of the measurement system. Moreover, the heart rate measurement results of one subject had to be removed from the data sample, because of too much noise on the signal. Thus, the dataset contains 19 measurements for skin conductance and 23 for heart rate.

Results

The bidders' level of physiological arousal for the three different value classes (*LOW*, *MEDIUM*, and *HIGH*) is depicted in Figure 2 and Figure 3. Figure 2 shows the referenced level of skin conductance, whereas Figure 3 shows the referenced level of heart rate.

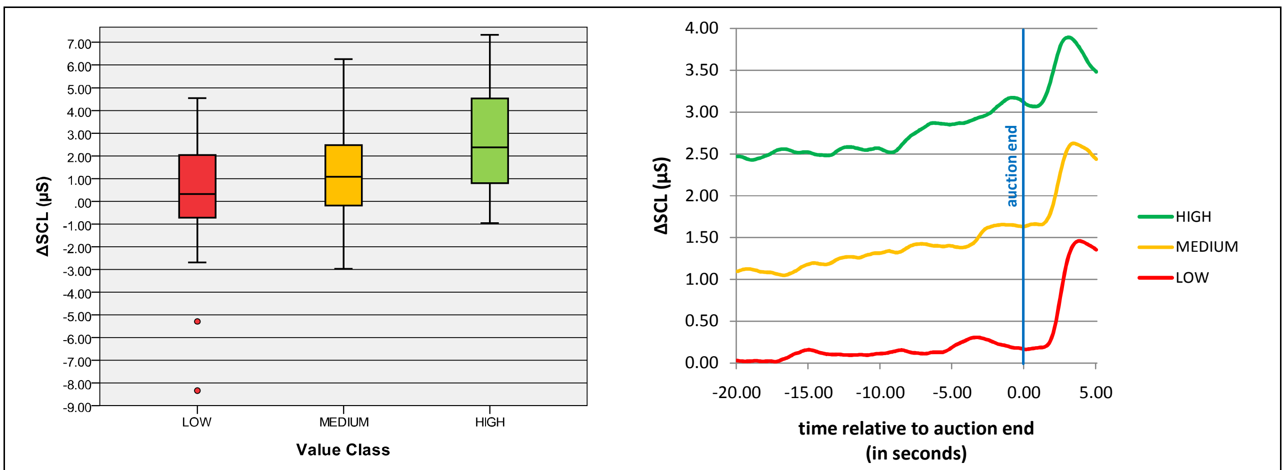

Figure 2. Skin Conductance Level (SCL) for Different Value Classes

As proposed in the session framework, a 5 minute rest period was conducted for every subject in the experiment. Therefore, in Figure 2, in Figure 3, and in the analysis, each value is referenced to an individual baseline measurement of arousal for the skin conductance level (ΔSCL) and the heart rate (ΔHR). Moreover, for every subject, one average value of ΔSCL and one average value of ΔHR were computed for each value class within the interval -20 to 0 seconds relative to the end of the auction. Thus, there are three observations for every subject for skin conductance and heart rate, respectively. The left parts of Figure 2 and Figure 3 show the distributions of these average ΔSCL and ΔHR values, respectively. The right parts show the grand average for the last 20 seconds relative to the auction end as a function of the value class. In order to allow the bidders' physiological arousal to return to a base value, a 1 minute rest period was introduced between two consecutive auctions.

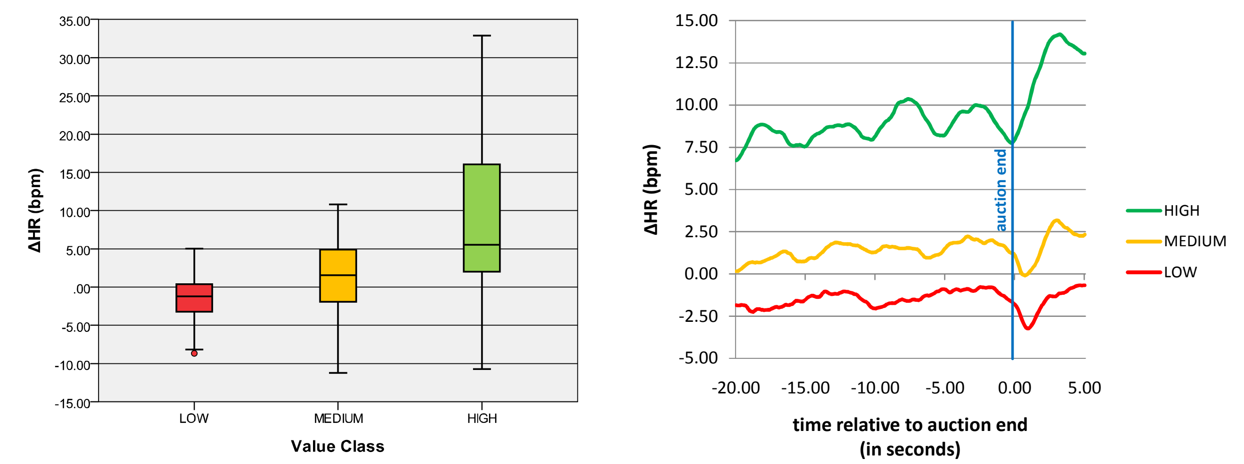

Figure 3. Heart Rate (HR) for Different Value Classes

With respect to the first research question if participants experience a higher degree of excitement when their probability of winning is higher, Figure 2 and Figure 3 clearly indicate that higher IPVs are associated with higher degrees of arousal. In order to test this hypothesis more formally, we conduct a Jonckheere-Terpstra tests for ordered alternatives on each participant's average level of ΔSCL and ΔHR, respectively. These tests reveal that the distribution of ΔSCL (n=57, $p < .01$) and the distribution of ΔHR (n=69, $p < .001$) increase significantly with the IPV class. Thus, we may conclude that the bidders' levels of arousal are in fact higher for higher IPVs. In other words, the bidders are more excited if they have a higher expected payoff in an auction.

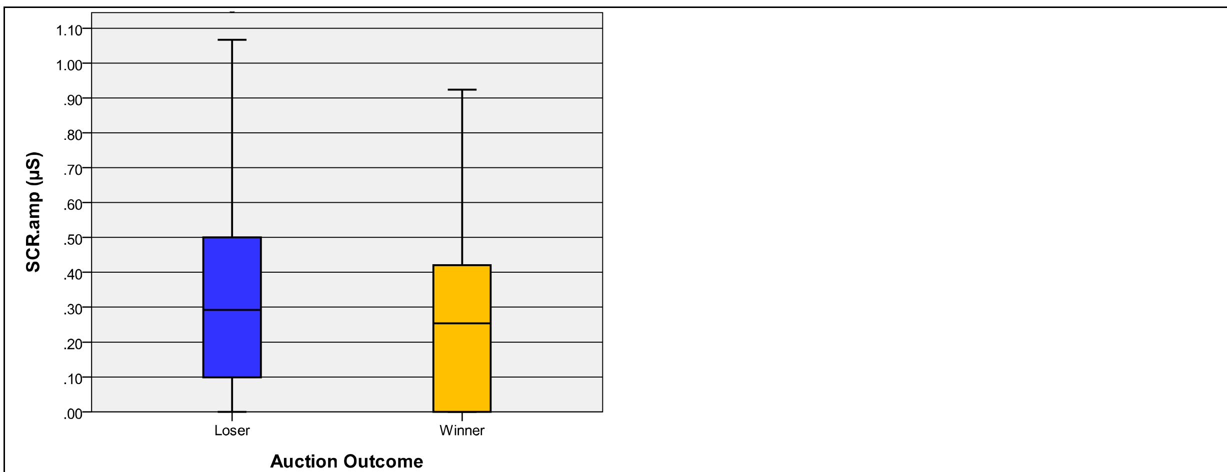

Figure 4. Skin Conductance Response Amplitude (SCR.amp) for Different Auction Outcomes

The bidders' log transformed average skin conductance response amplitudes (SCR.amp) in response to seeing the auction outcome are depicted as boxplots in Figure 4. The SCR.amp values are obtained by decomposing skin conductivity into its tonic and phasic components with the Ledalab analysis software (Benedek and Kaernbach, 2010). Following the recommendation of Venables and Christie (1980), all SCR.amp values occurring 1 to 3 seconds after revealing the auction outcome are then transformed *log(x+1)* in order to reduce the inherent left skewness of skin conductivity. In the analysis, we focus on the physiological reaction of a bidder in response to learning about winning or losing a Dutch auction.

A *t*-test reveals that the event of losing a Dutch auction is processed significantly stronger than the event of winning a Dutch auction (one-tailed *t*-test, 0.32 vs. 0.26, $p < .05$). This result is also in line with the neuropsychological data of previous research showing that the emotions associated with losing an auction are particularly strong in FPSB auctions (Delgado et al., 2008). We show that this also holds for Dutch auctions, which are strategically equivalent to FPSB auctions (Vickrey, 1961). The result seems intuitive. When a bidder decides to drop out of an auction, the bidder cognitively prepares for winning the auction. In contrast, when the bidder decides to stay in the auction, he or she literally fears that one of the other bidders stops the clock first. Therefore, as can be seen in the SCR.amp values, the emotional intensity when losing a Dutch auction is particularly high.

Discussion

The results of our exemplary market experiment show that the physioeconomic method is able to provide insightful results for the understanding of human decision-making that would not have been possible otherwise. First, we can establish that participants of a Dutch auction experience a significantly higher level of excitement during the auction when they are given a higher resale value for the commodity at stake. This is in contrast to the assumptions underlying the current theory on utility of suspense by Cox et al. (1983, p. 207) and Katok and Kwasnica (2008) which does not include the subject's expected payoff as a determinant of the size of his utility of suspense. To the contrary, Cox et al. (1983, p. 207) even discarded their initial theory of a utility of suspense, because they believed that such a utility should be independent of the expected (monetary) payoff. It is important to note, however, that our results do not discard the existence of a utility of suspense per se. In fact, our physiological measurements provide support that bidders are indeed more excited when playing a Dutch auction. As depicted in Figures 2 and 3, the levels of skin conductance and heart rate during the auction are on average higher than in the initial baseline period. In addition, further experiments would be necessary to investigate the relationship between the bidders' expected monetary payoff and arousal levels in more detail. The current experimental design does not allow to distinguish whether bidders' arousal is high in the HIGH value class (1) because the probability of winning is higher, or (2) because the face value of their IPV is higher, or (3) because of both. However, the current experiment is able to show the usefulness of the physioeconomic method, by which it was possible to identify a mismatch between the assumptions in the literature on how bidders would perceive suspense and bidders' actual perception. In this vein, physioeconomics can contribute to developing better economic theories, because it offers a set of experimental tools through which it is possible to test current theories on the relationship between emotions and economic activity in the light of ongoing emotional processes.

Second, physioeconomics can also be used to answer research questions more directly, e.g. by comparison of subjects' emotional responses under alternative scenarios. For instance, in the present experiment we are able to compare bidders' perception of winning vs. losing an auction, and found by analyzing the SCR.amp values, that the event of losing is perceived significantly stronger than the event of winning. The result seems intuitive in the context of a 'click-to-win' auction such as the Dutch auction: When a bidder decides to drop out of an auction, the bidder cognitively prepares for winning the auction. In contrast, when the bidder decides to stay in the auction, he or she literally fears that one of the other bidders stops the clock first. Therefore, the losing bidder often feels like the good has just been snatched away and the emotional intensity when losing a Dutch auction is particularly high.

Conclusions

In recent years, behavioral research has put a stronger focus on the role of emotions in human decision-making (Rick and Loewenstein, 2008). In this paper, we propose a methodological framework that we call physioeconomics, by which it is possible to measure psychophysiological correlates of human emotions during controlled laboratory experiments. In particular, we suggest that the adequate interpretation of subjects' skin conductivity and cardiovascular activity allows to assess emotional valence and arousal in response to a single information event (stimulus). In this way, these physiological parameters provide proxies for a subjects' (tonic) ongoing current emotional state, as well as their (phasic) immediate and anticipated emotions during economic activity. In contrast to brain imaging technologies (i.e. neuroeconomics or NeuroIS), the analysis of physiological parameters can be achieved with a comparatively low amount of measurement overhead and, thus, allows to collect empirical data for much larger sample sizes. Moreover, the autonomic responses that can be measured in physioeconomic experiments represent a core feature of emotional experience. Hence, this approach is particularly well-suited to analyze emotional aspects of human decision-making in electronic markets, such as auctions and negotiations, where decisions are taken by many subjects simultaneously. Further, the measurement devices are wearable and therefore this approach can also be employed in controlled field experiments. The possibility to assess the emotional state of many subjects simultaneously in non-stationary environments is the unique advantage of physioeconomics that makes it an alternative to neuroeconomics. However, of course brain imaging technologies are much more sophisticated in terms of identifying distinct brain regions involved in different aspects of decision-making beyond emotional experience. Thus, we understand these approaches as *complements* and not as substitutes.

In an exemplary physioeconomic experiment, which has been conducted according to our proposed methodological framework, we can show that physioeconomics is able to provide insightful results that advance the understanding of behavioral artifacts and would not have been possible otherwise. Similar to neuroeconomics, physioeconomics can be employed to test current theoretical presumptions as well as to test for differences in emotional activity directly. Thereby, a careful experimental design that allows for distinct information events (e.g. the auction outcome) and a distinguished set of feasible emotional responses (e.g. joy of winning or frustration of losing), is the key to a successful application of the physioeconomic method (cf. Adam et al., 2011). In particular, we are not convinced that physioeconomics will provide meaningful or reliable results in an uncontrolled environment in which different information events cannot be distinguished, either because they occur too frequently (e.g. during a stock market crash), or because the nature of the events is unknown to the researcher. Thus, the herein proposed methodological framework of physioeconomics is meant to guide future behavioral research in the successful execution of such studies such that the derived results are robust and repeatable.

Finally, the results of our pilot study and the physioeconomic method in general also bear important managerial implications. First, the skin conductance and heart rate data of our study provide direct insights into the bidders' emotional states while participating in an auction. The results show that the design of an electronic auction in fact has ramifications on the bidders' emotional processing and pronounce the importance for considering emotions as a driver of economic activity. In particular, it can be presumed that future market places will compete in emotions, rather than prices, and thus it will be vital for market engineers (Weinhardt et al., 2003) to better understand how electronic auctions can elicit emotions and which auction design parameters are most effective in achieving an exciting platform. Second, the methodology of physioeconomics provides the researcher with a structured methodology by which it is possible to systematically investigate the various parameters available to the designer of an electronic marketplace. In this vein, future research may also be able to disentangle the underlying emotional processes that distinguish static from dynamic auctions and lead to the well-known phenomenon of auction fever. Despite its practical relevance, today only little is known about the pathways through which auction fever affects bidding behavior (Adam et al. 2011). In this context, Malhotra (2010) noted: "research that focuses on understanding the seemingly visceral desire to 'win at any cost' is scant" and we are confident that physioeconomics can fuel this research.

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