Economics and Emotion: Institutions Matter

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Abstract

In two different types of institutions, English- and Dutch auctions, we collect heart rate data, a proxy for emotion, to test hypotheses based on findings in neural science about the effect of emotion on economic behavior. We first demonstrate that recording heart rates does not distort prices in these auctions. Next we consider whether knowledge of the intensity of a participant’s emotional state improves our ability to predict price setting behavior beyond predictions of price based on usual economic variables. Our answer is that “Institutions Matter.” In the Dutch (English) auctions we find (no) evidence that knowledge of emotional intensity affects our ability to predict price setting behavior. We then entertain the proposition that the cardiac system is an information system that processes economic events. We are able to show that this hypothesis is consistent with our observations and furthermore that the processes differ across institutions.
Introduction

The purpose of this paper is to extend what has been a core practice of experimental economics, namely asking if the truth of an economic proposition depends on the market institution in which it is studied. In particular, we ask if the impact of emotion is the same when similar economic choices are compared across institutions. The choices we examine are the choices of prices setters in English and Dutch auctions (Vickrey, 1961). We ask the degree to which knowledge of the intensity of the price setter’s emotional state will give us additional insight into these choices after controlling for the usual economic variables assumed to affect them. We find the role of emotion depends on the form of market institution studied.

Early in the development of experimental economics, market institutions were found to matter. Plott (1982) demonstrated that monopoly pricing depends on the institution in which trade occurs. A double auction with a single seller is more competitive than a posted offer auction with a single seller. Kagel (1990) showed that individual behavior can differ across institutions with identical equilibrium allocation implications, namely the English and Second-price auctions. Smith (1982) has outlined how the endeavor of laboratory experiments can be viewed as the empirical study of a mechanism’s ability to implement allocation goals such as surplus maximization.

Two recent studies relevant to this paper show that assessments of individual preferences can in fact change across institutions even when these assessment are made within minutes of one another. Using standard methods of assessing preferences in the English, First-price, and the Becker, Degroot and Marschak mechanisms (BDM), Berg, Dickhaut and McCabe (in review) demonstrate that individual preferences are more likely to be risk preferring in the English auction, risk averse in the First Price auction, and somewhat in between in BDM. In a related paper, Isaac and Jackson (1994) vary the BDM and First-price auction and find that assessed preferences in these two institutions also change. These results lead to the concern that either preferences may depend on the institution in which they are studied or something else is at work that is not captured by usual representations of preference.

Support for these concerns can be found in recent neuroscience research. Antonio Damasio and his colleagues have argued that emotions may be playing a fundamental role in choice (Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Damasio, Tranel, & Damasio, 1997; Damasio, 1994, 1996, 1999). They contrast results from experimental participants with no history of brain damage or psychological disease (“normals”) with results from patients with damage to the ventromedial prefrontal portion of the brain1. The Damasio team found that damage in the ventromedial area of the brain made patients less susceptible to the influence of negative stimuli such as losses

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1 The ventromedial prefrontal cortex has independently been shown to be active during the process of choice (Dickhaut, McCabe, Nagode, Smith, & Pardo, 2003; Glimcher, 2002; Rustichini, et al., this volume; Smith, Dickhaut, McCabe, & Pardo, 2002).
associated with draws from decks of cards. Their work implicated the role of emotions by examining heart rate and galvanic skin response, two psychophysiological proxies for emotion. Heart rate, the proxy for emotions that we use in this study, has been frequently studied for its ability to reflect emotional intensity (e.g., Ekman, Levenson, & Friesen, 1983; Lane & Schwartz, 1990; Lo & Repin, 2002; Sinha, Lovallo, & Parsons, 1992).

In this study we move the study of emotion in choice to real economic institutions, Dutch and English auctions. In particular we focus on the choices made in these auctions that determine prices. We apply the usual economic models used in the effort to predict pricing behavior in these auctions. Further, we ask if a limited knowledge of the relative intensity of emotion, as provided by heart rate, augments our ability to predict price setting behavior.

We begin this paper with a review of the two institutions, the English and Dutch auctions, and with an account of how the processing of economic and emotional information may modulate heart rate. These reviews motivate hypotheses on the differential role of emotion on price formation across these trading institutions. In the methods section, we discuss data collection, dependent measures, and data reduction.

The presentation of results has four parts. We first show that the presence of heart rate monitoring equipment does not distort the typical findings – group and individual behavior - in these auctions. Then we test whether we can improve on the standard economic models and make better predictions of prices in these auctions by augmenting them with the measurement of heart rate just prior to the determination of price. Our interpretation of the results of these tests are tempered by our understanding of the auction in which the choices occur. Emotions play a role for a significant subset of participants in the Dutch auction but not in the English auction. Finally, we turn to the cardiac system as an information processing system of economic signals. We find evidence for such a system and that the nature of processing varies across institutions.

**Differential emotion across trading institutions**

In this section we describe how English and Dutch auctions were implemented in our study and motivate why emotions (as proxied by heart rate) can differentially affect pricing behavior in these auctions.

**Auction structure**

As implemented in our laboratory, the auctions are represented by a circular clock on each of the four participants’ computer screens. In the English auction, the clock begins at $0 (in the noon position) and increases continually to a maximum of $2.50 (again at noon) at a rate of $0.05/second. Each participant starts out in the auction and presses a computer key to drop out of the auction. The last participant in the auction wins the auction at the price at which the next to last (third) participant exits. The last person to exit is the price setter and that participant’s price is the exit price. In contrast, the clock in the Dutch auction begins at a price higher than anyone is willing to pay for the item ($2.50 in our auctions). Thus each player is initially out of the auction. As the price
decreases the participant decides whether to enter the auction by pressing a computer key. The first participant to press a key wins the auction. The first person to enter is the price setter and that participant’s price is the entry price. Across institutions, to entice the participants to want to apply any profit motives they have, the computer generates a random draw of a dollar and cents amount, called the participant’s value, from $0.00 to $2.50, prior to the start of each auction. All amounts are equally likely in each draw. There is a separate and private draw for each participant. Should a participant win the auction, the difference between the participant’s private value and the price in the auction is the participant’s profit in that auction. For these reasons the two auctions are best described as private value English and Dutch clock auctions.

In the English auction reasoning is straightforward: a participant who wins an auction will make a profit as long as all the other participants exit at a price less than the winner’s value; the winner loses money when the last exit occurs at a price greater than the winner’s value. Therefore, we expect participants to stay in the auction until the price reaches their values and then exit. Further, they do not have to consider what other participants are doing to decide when to exit.

On the other hand, participants in the Dutch auction knows that it is possible to achieve a positive profit only after the clock has reached their values and that the profit will increase the longer they wait to enter. However, the participants cannot be sure of the profit while they wait because by staying out they are vulnerable to other participants’ winning the auction. The decision regarding when to enter may be affected by fears of what the others might do. A pair of emotional factors may influence pricing behavior here. First, the realization that a profit can be realized may produce a euphoria. Second, the problem of not knowing what others might do may induce anxiety. The euphoric effect may lead to entering the auction later, the anxiety to entering earlier.

**Emotions and heart rate**

We now turn to a more complete scientific explanation underlying why we expect to see differences in emotional behavior across auction institutions and why we expect to be able to detect this differential by monitoring participants’ heart rates. There are two main routes from the brain to the heart that enable visually-acquired economic information (e.g., auction data on computer screens) to have an essentially instantaneous impact on the rate at which the heart beats. The upper network projects dorsally (across the top of the brain and head) from visual areas in the occipital cortex to areas in parietal and frontal cortex where, we assume, value and current prices are represented and become the focus of conscious cognition. The lower network is ventral (across the bottom of the brain). It projects to the ventromedial prefrontal cortex, the region at the base of the brain that lies behind the eyes. The ventromedial prefrontal cortex has been shown to be critically involved in the processing of visceral information and emotion both with and without the mediation of consciousness (e.g., Bechara et al., 1994). Both networks communicate with the hypothalamus, the small but pivotal subcortical region that controls the two divisions of the autonomic system, the sympathetic and the parasympathetic.
The interplay of sympathetic and parasympathetic dominance and withdrawal controls the rate at which the heart beats. The feedback system linking the ventromedial prefrontal cortex and the hypothalamus (e.g., Bechara, Damasio, Damasio, & Lee, 1999; Dolan, Fletcher, Morris, Kapur, Deakin, & Frith, 1996) allows the representation and processing of emotional information to interact with the rate at which the heart beats. The dorsal (upper) network is known to support a variety of information processes including, but not limited to, calculation (e.g., Menon, Rivera, White, Glover, & Reiss, 2000), working memory (e.g., Marshuetz, Smith, Jonides, DeGutis, & Chenevert, 2000), and decision making (e.g., Bechara, Tranel, Damasio, & Damasio, 1996; McCabe, Houser, Ryan, Smith, & Trouard, 2001; Rogers et al., 1999). We assume that the dorsal stream of processing drives most auction behavior. Some of this behavior is likely to be relatively effortful (e.g., price setting choices in the Dutch) while some is likely to be relatively effortless (e.g., the English). When cognitive processes require relatively high levels of effort, the sympathetic division of the autonomic system becomes dominant and causes the heart to beat faster (Aasman, Mulder, & Mulder, 1987; Backs, 1995). In contrast, when processing is relatively easy, the parasympathetic system becomes dominant and causes the heart to slow down.

The ventromedial prefrontal cortex is likely to receive information about the auction from two sources, from visual cortex via the ventral network and from visceral information about the status of the body’s response to the auction environment. This interaction of visual and visceral information may or may not give rise to gut feelings, that is, to a conscious representation of an emotional response. Damasio (1994, 1999) argues that the ventromedial prefrontal cortex organizes experience and related emotions such that, when a decision situation is encountered, its characteristics (e.g., values and prices) elicit recall of past emotional experiences consistent with the situation. The reemergence of these “emotion settings,” in turn, may influence how the choice is made (e.g., Loewenstein, 1996; Mellers, Schwartz, Ho, & Ritov, 1997, 1999; Slovic, Finucane, Peters, & MacGregor, 2002). Rustichini et. al. (this volume) find evidence that for some economic decisions choice behavior appears to be shifted more toward upper regions of the brain such as the parietal and frontal lobes, a result which makes plausible the notion that in other economic choices, such as the English and Dutch auctions, decisions may invoke different processes and result in different choice observations.

Heart rate and emotions have been examined in a number of studies (e.g., Collet, et al., 1997; Levenson, Ekman, & Friesen, 1990). Usually the participant is put in a setting that is designed to induce an emotional response, e.g., viewing pictures, reading text, or acting a part in a play. While engaged in the task, the participant’s heart rate is monitored and questions are asked to assess the participant’s emotional state. Typical results are shown in Figure 1. The horizontal axis shows the seven standard categories of emotion. The vertical axis indicates the relative elevation of heart rate above a baseline measurement. Many of the basic emotions induce a change in heart rate. We measure heart rate in our study using a standard three-electrode electrocardiogram.
Figure 1

![Graph showing heart-rate response to induced emotions](image)

Heart-rate response to induced emotions (solid bars from Ekman, Levenson, & Friedman, 1983; open bars from Sinha, Lovallo, & Parsons, 1992).

The effect of context on brain activation

There is ample precedent for suggesting that minor contextual changes (e.g., different rules for auctions) may trigger profoundly different patterns of neuronal activation (along the dorsal or ventral path) which, in turn, may be reflected in changes in observable behavior (price formation). For example, consider the Stroop task (Stroop, 1935). In the Stroop task, the stimulus is a word that names a color, e.g., the word red. The contextual change is provided by the color of the ink that the word is printed in. The ink may or may not match the color’s name. For example, if the word is red it might be printed in red ink or green ink. The participant’s task is to say the word that corresponds to the color of the ink. It has long been known that both reaction time and accuracy are strongly influenced by whether or not the ink matches the word (for a review see Milliken, Lupianez, Debner & Abello, 1999). Pardo, Pardo, Janer, and Raichle (1990) and Carter, Mintun, and Cohen (1995) used positron emission tomographic (PET) imaging to document that this minor change in context evokes different patterns of neuronal activation. In particular, Pardo found that the ventromedial prefrontal area is preferentially activated in the no match condition.

Pardo’s finding has implications for our study of price formation across auction institutions. The Stroop task preferentially activates the ventromedial cortex, the part of the brain that processes visceral, emotional information, when the experimental stimulus...
presents a conflict. We propose that the environmental differences between the Dutch and English auction also initiate different neuronal networks and that this differential processing leads to different pricing behavior in these auctions. The proposition here is that the English auction, as a collection of stimuli, induces less emotional processing than the Dutch auction and that this difference can in principle be detected indirectly by measuring heart rate.

Method

Participants

Twenty-four undergraduate students (ages 18 to 29, mean age 22.4; 14 females, 10 males), in groups of four, participated in a block of 60 Dutch auctions followed by a block of 60 English auctions. They received a $5.00 show-up award and their cumulative earnings from 120 auctions.

Procedure

Participants sat at separate computer terminals surrounded by privacy barriers. After reading the instructions and signing the consent form, they received five practice Dutch and five practice English auctions. They then played 60 Dutch followed by 60 English auctions. Upon completing both sets of auctions, participants privately received their cumulative winnings. The mean amount won in the auctions was $12.35 with a high of $18.60 and a low of $7.25.

At the beginning of each auction, the computer terminal privately revealed the participant’s value for that auction (i.e., the amount the experimenter will pay the participant for owning the asset at the end of the auction). For each participant, this value was randomly drawn from a uniform distribution, $0.00 to $2.50. The random nature of the endowment and its distribution were public knowledge. Values during the auctions remained private information.

Figure 2 shows the computer display used for both types of auctions. At the start of the auction the outstanding price was $0.00 in the English and $2.50 in the Dutch and was represented by the noon position of the clock. Throughout the experiment, the current price was shown graphically using the clock in the center of the display and numerically (in cents) in the lower right corner of the screen. In the English (ascending price) auction, shown in Figure 2, the clock swept clockwise at a constant rate, five cents per second. In the Dutch (descending price) auction, the clock swept counterclockwise at five cents per second. The display simultaneously changed both the numerical and graphical representations of price. The bottom left corner of the screen indicated the participant’s cumulative profits (in dollars) and current value (in cents), both of which remained private information. In contrast, current prices and the number of participants remaining in the auction were public information. The top right corner of the screen displayed the number of participants remaining in English auctions.
Heart rate

Three-electrode electrocardiographic data were recorded using 3M red dot silver/silver-chloride bio-potential electrodes, shielded leads, and four Biopac Systems ECG100C preamplifiers. A separate preamplifier was used for each participant. The settings for the preamplifiers include a low-pass filter and a 50 dB 60 Hz notch filter. A proprietary software program (Pearson Technical Software, Minneapolis, MN) running on a 300 MHz Wintel PC sampled the ECG signals at 1000 Hz. This program uses a dual threshold technique to identify R-wave spikes and filter out movement artifacts and other sources of noise in the signal. It captures the times of the R-waves spikes (the electrical signal that triggers the contraction of the ventricles) and appends packets of 100 spike-times to separate files for each participant. Upon completion of data acquisition, each file contains an hour-plus-long time-series of the times when the heart beats. The 24 time series of heart-beat times, one per participant, are the raw data for our analysis of heart rate and auction structure.

The analysis consists of a comparison of the mean values of heart rate in four-second intervals on either side of an auction event. The means are calculated in the following manner. First the time series of observed heart-beat times was converted to a time series of instantaneous heart rate (in beats per minute, bpm) so that larger values indicate more rapid rates. Second, a linear regression was fit to each time series individually to identify and remove any long-term (generally decreasing) trend that might be associated with accommodation to the experimental setting and/or fatigue. The residuals from the regressions were then standardized within each participant to create 24 time series of z-scores. All statistical analyses were performed on the z-scores of residual
heart rates. The standardization allows aggregation across participants under assumptions of independence across participants and auctions.

**Results**

**Replication of price behavior in auctions**

Figure 3 plots of the difference between the exit price (the price at which the price setter exited) in the English auction and the price setter’s value against the sequence number of English auctions. Of the 360 observations, 319 plot within 8 cents of the predicted value. This result aligns with previous findings (e.g., McCabe, Rassenti, and Smith, 1990, 1991).

![Figure 3](image_url)

The difference between the value of the last person to exit and the exit price in the English auctions. The value of the third person out appears to play a pivotal role in price determination, replicating known results without heart rate equipment.

Figure 4 is a plot of the price of the winning entry in the Dutch auction against the winner’s value. The upper line has a slope of 1.00 and represents entry at the participant’s value. Such behavior would produce no profit. The lower line has a slope of 0.75 and represents the predicted price assuming risk neutrality in a four-person auction.
auction. Of the 360 observations, 327 (91%) lie between the two lines, consistent with the assumption that participants were risk averse. This result also aligns with previous findings.

Observed entry prices plotted against value in the Dutch auctions. The thicker, lower line represents the risk neutral bid for a four-person auction. The graph appears to indicate risk averse behavior since the group of subjects tends to pay a premium over expected value to win the auction.

We infer from the data shown in Figures 3 and 4 that the presence of the electrocardiographic recording equipment did not interfere with the internal processes and overt behavior that support price formation in the experiment. Further, the graph of Figure 3 suggests that a large proportion of observations in the English institution can be explained by knowing the value of the price setter in the auction. We assess that claim in the following section.

**Coefficients on value in English and Dutch auctions**

We argued that the exit price of the price setter (third-person-out) of the English auction would be (at or near) that person’s value. If that were the case, then knowledge
of heart rate should add little to our ability to predict prices. To assess if heart rate yields any additional information beyond what has traditionally been used to explain individual behavior in the English auction, we regressed the exit price on the price setter’s value and the average z score of the price setter’s heart rate during the 4 seconds preceding the exit time. For each participant we identified the auctions in which the participant was the price setter and for those auctions collected the exit price, the participant’s value and mean heart rate during the four seconds prior to exiting the auction. The columns on the left of Table 1 show the regression coefficients on value and their t statistics for the data from price setters in the English auctions. The coefficients on value are significant at the .05 level for all but one of the participants. The coefficients are within 0.1 of 1.0 for 20 of the 24 participants. We interpret this result to reveal an instance in which received economic theory, a dominant strategy equilibrium, is consistent with the observed data.

Table 1

Estimated value coefficients in the English auctions and risk coefficients in the Dutch auctions.

<table>
<thead>
<tr>
<th>English</th>
<th>Dutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value coef.</td>
<td>Player</td>
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<tr>
<td>1.004</td>
<td>.000</td>
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<tr>
<td>1.055</td>
<td>.000</td>
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<tr>
<td>1.002</td>
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<td>0.654</td>
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<td>1.002</td>
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To assess the degree to which knowledge of heart rate adds to our ability to predict prices in the Dutch auction, we regressed the entry value of the winner (the price setter in the Dutch auction) on the winner’s value and z-score for heart rate during the four seconds immediately prior to entering the auction. By working with a subset of the observations in this auction (assuming constant relative risk aversion for the participant), we can derive an estimate of the risk coefficient using the value coefficient for the participant (Cox, Smith and Walker, 1982). Risk coefficient estimates less than one indicate risk aversion. The columns on the right of Table 1 show the risk coefficients and their significance levels from the regressions on value and heart rate for price setters in the Dutch auctions. Elements of the participants’ behavior were generally consistent with the assumption of risk aversion. The estimates of the risk coefficient are significant at the .05 level for all participants. We now turn to the analysis of heart rate and its influence on our ability to predict outcomes in these auctions.

**Coefficients on heart rate in English and Dutch auctions**

As discussed in the previous section, we regressed exit (entry) prices against value and heart rate in the English (Dutch) auctions. Table 2 lists the t-statistics of the coefficients on heart rate and their significance levels. Figure 5 is a histogram showing the distribution of the t-statistics on heart rate. The solid bars show the distribution for the English auctions and the open bars show the distribution for the Dutch.

**Figure 5**

Comparison of the distributions of the absolute values of the t-statistics for heart rate in the regressions of exit (entry) price on value and heart rate in the English (Dutch) auctions. The distribution for Dutch is significantly shifted to the right.
Table 2

Absolute values of the t-statistics for the regression coefficients for heart rate and their significance levels in the regressions of exit (entry) price on value and heart rate in the English (Dutch) auctions.

<table>
<thead>
<tr>
<th></th>
<th>English abs(t-stat)</th>
<th>P</th>
<th>Player</th>
<th>Dutch abs(t-stat)</th>
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The t-statistics for heart rate prior to the entering the Dutch auction have a strong tendency to have a higher level of significance than the t-statistics for heart rate prior to the exiting the English auction. Comparison of the cumulative distributions using the Kolmogorov 2 sample statistic reveals that the tendency is significant at the 5% level. We argue that this is evidence that emotional factors, as represented by instantaneous heart rate, differentially affect our ability to predict the price across these auction institutions. And thus knowledge of emotions differentially, and in a fundamental way, affects the ability to predict behavior. This differential tells us that institutions matter.
This result holds through time and is robust to different constructions of statistical tests as well as different specifications of statistical models. Furthermore, a binomial test addresses the likelihood of obtaining the observed significance levels in the Dutch auctions (under the null hypothesis that heart rate does not affect price). The likelihood of obtaining 7 or more at the 10.0% level is less than .008.

These basic findings are also robust when an interaction term is included in the regression, when we apply a log transform to value, and when we look at the direct correlation between heart rate and exit (entry) price. Furthermore the effect does not diminish if we constrain our observations to the last twenty auctions. Knowledge of heart rate enhances our ability to predict the basic behavioral outcome in the Dutch auction but does not help us predict prices in the English auction.

The cardiac system as an economic information system

Having found that heart rate has a different influence on predictive power, we turn to the issue of why this result comes about. We suggest that the cardiac system is itself an economic information processing system that is constantly being influenced by signals from the brain about changes in the environment. In short, we view heart rate as a carrier of (economic) information.

To elaborate, economic signals arise from the environment (in this experiment the computer screen) in the form of values, the current price in the auction, and the exit or entry of other participants. This information hits the retina, is transmitted via the thalamus to the occipital lobe where it is reconstituted and sent to the frontal lobe and also back to (different nuclei in) the thalamus. From there the information goes to the hypothalamus which then excites the vagus and secretes hormones that orchestrate the behavior of the heart. Thus in principle, the heart rate can change as the economic environment changes.

In our study, the participants received private economic information at the start and end of every auction: they were endowed with their values at the start of an auction and their profits were (not) updated upon winning (not winning) an auction. The time when auctions ended was public information for all participants as was the time when participants dropped out of the English auctions. To examine systematic variations in the participants’ heart rates in response to these economic events, we graph and compare the mean heart rates during the four seconds prior to an event and the four seconds after an event. We use individually-determined z-scores to aggregate results across participants. The mean z-scores of heart rate are grouped by the participants’ values (e.g., values above or below the median amount, $1.25). They are aggregated across all events of a specific type (e.g., the endowment with a value) and across all auctions of a given structure (Dutch or English). Because values are randomly assigned to participants across auctions, every participant is represented several times within each set of results.
English auctions

Figure 6 shows the mean z-scores of heart rate in the four seconds immediately before and after the release of economic information in the English auctions. The three pieces of information are the receipt of value information at the beginning of the auction (private information), the time when the second participant exits the auction (public information), and the time of the end of the auction when the third participant drops out (public information) and the remaining participant wins. The upper panel shows the change in mean heart rate for all participants with values greater than or equal to $1.25, the midpoint of the uniform distribution from which values are randomly assigned. The lower panel shows the change in mean heart rate for participants with values less than $1.25.

Heart rates in the English auction were generally below the global mean for the entire experiment. The relatively low values are unlikely to reflect a sequence effect (the block of 60 English auctions followed the block of 60 Dutch auctions) because linear trends in the observed time series of heart beats have been removed on a participant-by-participant basis. Note the z-score of zero can be thought of as corresponding roughly to the overall mean heart rate across participants of approximately 85 beats per minute.

The upper panel of Figure 6 shows the change in mean heart rate for participants with values of $1.25 or greater. The drop in heart rate at the beginning of the auctions is marginally significant, \( p < .074 \) (df = 674) using the Wilcoxon ranked sums test. It may reveal relaxation and a temporary ‘switching off’ - an adaptive response. There is no significant response to information that the second person has dropped out or to the end of the auction for participants with relatively high values.

The mean heart rate for participants with values less than $1.25 is shown in the lower panel of Figure 6. For these participants, heart rates remain below the global mean throughout the English auctions. There are no significant responses to the receipt of a low value and to information that the second person has dropped out. The increase in heart rate at the end of the auctions to near the global mean is significant, \( p < .046 \) (df = 655) using the Wilcoxon ranked sums test. This finding suggests that participants with relatively low values maintain a uniform indifference or detachment as the auctions proceed but become aroused at the end of an uninteresting auction when they will soon receive a new value (at the beginning of the next auction).
Change in the average z-score of heart rate across events in the English auctions: upon receiving the private value, when the second player exits, and at the exit price. The upper panel shows the heart rates for all players with values greater than or equal to $1.25, the midpoint of the uniform distribution from which values were randomly assigned. The lower panel shows heart rates for players with values less than $1.25.
Dutch auctions

Figure 7 shows the mean z-scores of heart rate in the four seconds immediately before and after (1) the beginning of the Dutch auction when participants receive a value and (2) the end of the Dutch auction when one of the participants wins the auction. The upper panel shows the mean heart rates for participants with values greater than $1.25 and the lower panel the mean heart rates for participants with less than $1.25. In marked contrast with the English auctions, Figure 6, heart rates during the Dutch auctions, Figure 7, were often above the global mean.

The upper panel of Figure 7 shows that the mean heart rate for participants with values above $1.25 is well above the global mean at the beginning of the auction but falls below the mean before the end of the auction. It drops precipitously at the end of the auction. The drop in heart rate at the end of the Dutch auctions is significant, $p < 0.011$ (df = 588) using the Wilcoxon ranked sums test. These data suggest (1) participants of Dutch auctions who received high values experienced the elevated heart rates associated with the onset of sympathetic dominance, and (2) winning a Dutch auction was marked by a sharp decrease in heart rate, a pattern consistent with a release from sympathetic dominance.

A post-hoc analysis found that winners are primarily responsible for the sharp drop in mean heart rate at the end of the auction. The drop in heart rate for winners, not shown, is significant at $p < 0.020$ (df = 292) while the drop for participants with the third highest value is not significant, $p > 0.20$ (df = 295). Only winners appear to experience the release from sympathetic dominance.

The lower panel of Figure 7 shows that the mean heart rate for participants with low values jumps upon receiving those low values and then drops below the mean before the end of the auction. The jump in heart rate was unexpected but significant, $p < 0.001$ (df = 587) using the Wilcoxon ranked sums test. It is experienced by participants with both the lowest and second highest values at $p < 0.007$ (with df = 291 and 295 respectively). The surge in mean heart rate may reveal a flash of irritation at receiving a substandard value that thwarts an opportunity for profit. It appears that nobody likes to receive a bad value in the Dutch auction.

A post-hoc analysis of the two statistically significant heart rate responses shown in Figure 7 looked for time-dependent patterns in that might be indicative of accommodation to the structure of the Dutch auction. The analysis subdivided the 60 auctions into three blocks of 20 (auctions 1-20, 21-40, and 41-60) and conducted separate Wilcoxon tests for each of the three blocks. Figure 8 presents the data. The horizontal axis represents the three blocks of time. The upper panel shows the drop in heart rate for participants with high value at the end of the auction when one of them wins. The lower panel shows the surge in heart rate at the beginning of the auction for participants who receive low values.
Change in the average heart rate across events in the Dutch auctions: upon receiving the private value and at the end of the auction. The upper panel shows heart rates for players with the values greater than $1.25. The lower panel shows heart rates for players values less than $1.25.
The time-dependency of the two significant changes in heart rate in response to the release of economic information in the Dutch auctions. The 60 auctions were subdivided into three blocks of 20. The upper panel shows the change in average heart rate for players with the values above $1.25 at the end of the auction, when one of them wins. The lower panel shows the change in heart rate for players as they receive the values below $1.25 at the beginning of the auction.
The upper panel of Figure 8 shows that the sharp drop in heart rate at the end of the auctions seen in the upper panel of Figure 8 is limited to the first 20 auctions. The Wilcoxon ranked sums test reveals that the drop in heart rate at the end of the auctions is highly significant during the first block of 20 auctions, \( p < 0.003 \) (df = 193). The smaller drops during the later blocks are not significant. We interpret this result to indicate that sympathetic withdrawal upon winning a Dutch auction is pronounced at the beginning of the session and becomes muted as time goes on. This trend suggests that participants-as-winners adapt to the structure of the Dutch auction.

The opposite pattern is seen in the bottom panel of Figure 8. The surge in heart rate when receiving a relatively low value in the Dutch auction does not become evident until the second and third blocks of time. The p-value for the first block of time is not significant, \( p > .26 \), but is significant thereafter, \( p < .001 \) for the second block and \( p < .003 \) for the third block. These data suggest that our participants learned to appreciate the negative implications of receiving a low value as they gained experience. We interpret the surge in heart rate to reflect irritation at the prospect of a bad outcome, i.e., not getting the chance to obtain a profit. Their inferred irritation is not a reaction to a bad outcome but rather is anticipation of that bad outcome. We interpret this result to reveal an adaptive, visceral response to economic information. This response is not evident in overt behavior but can be uncovered by observing the cardiac information processing system.

Conclusion

This is a first study to contrast the relationship between a psychophysical proxy for emotion and the choice behavior of individuals across two well-known market institutions, the English and Dutch clock auctions. Like other received knowledge from experimental economics, we have found that institutions do, in fact, matter. The economic behavior of individuals in the English-clock auction is less mediated by emotional factors than it is in the Dutch-clock auction.

Such a result should be interesting to economists for at least two reasons. First, economists are generally interested in price. Emotion is not usually considered a determinant of price. In this study we adopt heart rate as a proxy for emotion to take a first step toward relating observed price to emotional factors. We have shown that this effort has promise. Second, there are clear policy implications of this type of research. A. Damasio and his colleagues have argued that, depending upon context, emotions can either augment or detract from decision making. Given this contextual dependence, there may be times in which it is desirable to choose an economic institution based on the emotional impact it has on the participants’ pricing behavior. For example, the English-clock auction may be much less affected by emotions than a similar increasing-price auction with a human auctioneer even though, from the standpoint of received economic knowledge, individual’s behavior in these auctions should be the same.

Of course, given our work to date, we can only say that our findings are consistent with the hypothesis that emotions are proxied by changes in heart rate in these institutions.
and that heart rate in one institution provides additional explanatory power beyond typical economic variables.

Much additional work can be done. First, it is desirable to attempt to find a converging and discriminating set of measures of emotion. Heart rate is just one metric; others include galvanic skin response and subjective verbal reports. Until we perform studies using more discriminating metrics it will be hard to say precisely which emotions are at work and if, in fact, we are actually observing a truly emotional response.

There are a wide variety of institutions that are also available for study. How does a double auction designed to improve bid and ask offers compare with the two auctions we have already studied? Are emotional factors dampened or increased by the presence of a human auctioneer, by public bidding, or by casual observers? Can we elaborate the determinants of contextual sensitivity to uncover when and why institutions matter?

Typically the phrase “Institutions Matter” has been used by economists to apply to wider societal issues. The rules and means governing economic transactions have been used to assess the relationship between property rights and the performance of a society (North, 1994), the relationship between forms of deposit insurance and the existence of moral hazard (Allen, 2001), as well as the interplay between a well-functioning economy, its fairness, and corruption (Broadman and Recantini, 2001). Such institutions may also not be immune to having emotions play a role.
References


