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The neural basis of regret and disappointment and its influence on pricing decisions: insights from self-agency and other-agency responsibility pricing experiments

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Abstract

By incorporating neuroscientific methods into the classical pricing framework, we studied participants' neural responses to regret and disappointment, measured by ERP waveforms and scalp potential spatial distributions. We observed significant neural activation for underpricing and overpricing regret, as well as marginally significant neural activation for underpricing disappointment, whereas no notable activation was found for overpricing disappointment. We found heterogeneity in individual ERP responses and used negative differences in FRN amplitudes across cases as representative variables for underpricing and overpricing regret. These measures were then employed to investigate their effects on participants' pricing behaviors. Our findings contradict the common belief in behavioral economics that individuals strategically make decisions to avoid regret-related negative emotions.

Keywords: regret, disappointment, event-related potentials (ERPs), pricing decisions, pricing experiments

1 Introduction

Neoclassical economics focuses on the rational homo economicus and studies the choices of rational market participants and their outcomes. However, with the development of behavioral economics, attention among economists has shifted to various behavioral biases that contravene the rationality hypothesis, resulting in market prices and quantities that are inconsistent with the predictions of the neoclassical model. Regret, rooted in counterfactual thinking, is defined as the negative emotion experienced when one wishes a different decision had been made in the past for a more favorable outcome in the present. It is regarded as one of the most extensively studied behavioral biases.

Pioneered by Fishburn (1982), Bell (1982), and Loomes and Sugden (1982), regret theory posits that the final outcome is determined by both the action chosen by the decision-maker and the state, which remains unknown to the decision-maker at the time of decision-making. Individuals experience regret when, after observing the outcome, they realize that an alternative action would have produced a more favorable result. As a result, numerous empirical and experimental studies have focused on scenarios involving both freely chosen actions and uncertain states—such as gambling, financial investments, and price auctions—to examine how agents behave irrationally under the influence of regret.

However, most early studies only verify the presence of regret indirectly by analyzing agents' irrational behaviors, rather than directly quantifying the individual level of regret. As a result, they are unable to predict how variations in market participants' regretful emotions might affect their future behaviors. Some researchers (Zeelenberg et al., 1998; Van Dijk, 1999; Van Dijk and Zeelenberg, 2005) attempt to capture individual differences in regret intensity by asking questions like, "How much regret do you feel?" using Likert-type scale responses. However, the accuracy and objectivity of this method remain questionable.

Furthermore, researchers often overlook that market participants may not always have full freedom of choice. Specifically, sellers in different market structures exhibit varying degrees of pricing power. For example, a monopolistic firm sets its price independently, while perfectly competitive firms act as price takers and must passively accept the market price. Disappointment, another type of negative emotion arising from counterfactual thinking—when an alternative state could have led to more favorable outcomes—can occur even in the absence of active decision-making. Considering disappointment further calls into question the reliability of the traditional emotion scale method. It is uncertain whether participants can accurately distinguish and associate their

negative emotions with the verbal descriptions of regret or disappointment. Even if they can, the difference between regret and disappointment may not be merely a matter of degree.

Emerging neuroscientific techniques, such as electroencephalography (EEG) and functional magnetic resonance imaging (fMRI), offer promising methods for objectively measuring the extent and mechanisms of regret and disappointment at the individual level. These techniques record the brain's electrophysiological activity associated with decision-making and information processing. Event-related potentials (ERPs), derived from EEG signals, directly reflect neural responses to counterfactual thinking—including both regret and disappointment—when individuals learn "what is" and compare it to "what might have been" under different choices or states.

Therefore, our paper introduces neuroscientific methods into classical pricing experiments. In the self-agency responsibility pricing experiment, participants, acting as monopolistic sellers, actively choose whether to set a high or low price and then learn whether the incoming consumers are willing to pay a high or low price. If a participant sets a price lower than the consumer's willingness to pay, she experiences "underpricing regret", associated with counterfactual thinking about setting a higher price. Conversely, if the participant sets a price higher than the consumer's willingness to pay, she experiences "overpricing regret", associated with counterfactual thinking about setting a lower price. Additionally, we conducted other-agency responsibility pricing experiments, where participants, acting as perfectly competitive sellers, passively observe whether the market price set by the computer is high or low, and then learn about the consumers' willingness to pay. Accordingly, the participant experiences "underpricing disappointment" or "overpricing disappointment", associated with counterfactual thinking about whether the computer-simulated price could have been higher or lower.

By plotting the average ERP waveforms across different cases, we directly investigated the overall effects of the two types of regret and two types of disappointment described above. The amplitudes of participants' feedback-related negativity (FRN) and P3—two major peaks of the brain's electrophysiological activity—were significantly affected by both types of regret and was significant at the 10

Furthermore, we explored individual levels of regret and disappointment. First, we illustrated the heterogeneity in participants' ERP waveforms associated with regret and disappointment. We then showed that the negative differences in FRN amplitudes between cases with and without the two types of regret and underpricing disappointment were significantly correlated with the negative differences in the corresponding emotion scale ratings between the same cases. Additionally, we observed a significant positive correlation between participants' negative differences in FRN amplitudes for underpricing and overpricing regret. Therefore, we concluded that the FRN measures defined above were suitable representative variables for underpricing and overpricing regret.

Finally, we used linear and logit regressions to examine the effects of FRN measures for underpricing and overpricing regret on participants' pricing behaviors. Our findings indicated that the higher the level of underpricing regret, the less likely participants were to set a high price. Additionally, the higher the level of overpricing regret, the greater the positive impact of previous occurrences of the overpricing case on participants' probability of setting a high price. In conclusion, participants were unable to "rationally" adjust their decisions to avoid the negative emotions associated with regret. We suggest several possible explanations, including hope for a different outcome and negative emotion reinforcement; however, the precise reasons require further investigation.

The remainder of this paper is organized as follows. First, we review the previous literature. Next, we outline the materials and methods used in the study. Then, we present and discuss the main results. Finally, we conclude with a summary of findings and implications.

2 Related literature

Our study is closely related to the behavioral economics literature on regret.[1] Fishburn (1982), Bell (1982), and Loomes and Sugden (1982) independently propose the regret theory, incorporating the disutility from counterfactual thinking—that a result would have been more favorable had an alternative choice been made. Early empirical papers, such as those by Loomes and Sugden (1987), Loomes (1988a,b, 1990), Starmer and Sugden (1989), and Starmer (1992), validate the implications of regret theory using lotteries. Since then, numerous studies have applied the concept

[1] Bleichrodt and Wakker (2015) conduct a comprehensive survey on the development of regret theory and its applications.

of regret or its implications across various scenarios. For instance, Syam et al. (2008), Nasiry and Popescu (2012), Diecidue et al. (2012), Jiang et al. (2017), explore consumer regret and examine how anticipated regret influences consumer and firm decisions.[2] Barberis et al. (2006), Muermann et al. (2006), and Michenaud and Solnik (2008) consider investors' regret and analyze its impact on their asset purchasing and allocation decisions. Filiz-Ozbay and Ozbay (2007), Engelbrecht-Wiggans and Katok (2007, 2008, 2009), theoretically explain and experimentally test bidding behaviors in first-price sealed-bid auctions, focusing on "loser regret" (losing but could have won at a lower, favorable price) and "winner regret" (winning but could have won at a lower price) because what seems to be the best action ex ante may not be the best ex post. Davis et al. (2011) suggest that the results of their second-price sealed-bid auction experiments are better explained by sellers' anticipated regret, rather than risk aversion or probability weighting. Li and Liu (2022), in economic scenarios most similar to our study, assume that the seller experiences regret and solve static and dynamic pricing models to maximize her total expected profit, considering both overpricing and underpricing regret in information-theoretic contexts. However, we experimentally study the pricing strategies of sellers (as participants) and directly estimate the levels of overpricing and underpricing regret by measuring the associated ERPs. Notably, our regression results show that participants with higher levels of underpricing regret are more inclined to set a low price, which contradicts the theoretical predictions of Li and Liu (2022).

Besides regret, a stream of behavioral economics literature also incorporates another type of counterfactual thinking: disappointment. Bell (1985) and Loomes and Sugden (1986) propose the disappointment theory, in which a more favorable outcome would have been achieved with an alternative state (as opposed to an alternative action in the regret theory). Inman et al. (1997) combine the theories of regret and disappointment, summarizing three components of consumers' utilities, namely expected performance, disappointment, and regret. As two of the most important behavioral biases arising from counterfactual thinking, "regret stems from bad decisions", while "disappointment stems from disconfirmed expectancies", according to Zeelenberg et al. (1998, 2000). Many researchers are inspired by their essential differences, identifying and discriminating their respective roles in decision-making using various methods. In some experiments, subjects are asked to score their subjective feelings with Likert-type scale responses regarding their regret or disappointment (Zeelenberg et al., 1998; Van Dijk, 1999; Van Dijk and Zeelenberg, 2005; Zhang et al., 2005; Barberis et al., 2006), and appraisals in different dimensions (Van Dijk, 1999; Frijda et al., 1989). Marcatto and Ferrante (2008) develop a new questionnaire, the Regret and Disappointment Scale (RDS), to assess the emotions of regret and disappointment simultaneously. In contrast, other studies manipulate experimental conditions and compare results in active and controlled groups. Connolly et al. (1997), Zeelenberg et al. (1998, 2000), Van Dijk and Zeelenberg (2002), Ordónez et al. (2000) and Giorgetta et al. (2012) claim that regret is more related to self-agency responsibility, and disappointment is more related to other-agency responsibility. They thus compare choices made by the participants themselves (with regret) and by the computer (with disappointment). Zeelenberg et al. (1998) ask participants to recall an instance of intense regret or disappointment and to indicate what they felt, thought, felt like doing, did, and were motivated to do during the experience. However, as noted by Marcatto and Ferrante (2008), these methods rely on the implicit assumption that participants can easily and accurately associate their feelings with verbal labels. Unlike previous behavioral approaches, we recorded ERPs during self-agency and other-agency responsibility pricing tasks to provide an electrophysiological measure that complements self-reported assessments of regret and disappointment.

The differences between regret and disappointment have also been extensively studied in neuroscience, with a particular focus on the underlying neural mechanisms of decision-making. Most early neuroscientific studies asked participants to choose between two gambles and compared neural processing when revealing only the outcomes of the chosen gambles to when revealing the outcomes of both gambles (Camille et al., 2004; Chua et al., 2009; Coricelli et al., 2005). However, economists have long noted that regret can still exist even if participants receive no feedback about the outcomes of the other, unchosen options (Bar-Hillel and Neter, 1996; Zeelenberg et al., 1998, 1999; Connolly and Zeelenberg, 2002). More recent research, such as Nicolle et al. (2011), Giorgetta et al. (2013), Zhang et al. (2022) has applied the self-agency vs. other-agency responsibility framework from behavioral economics. Both Giorgetta et al. (2013) and Zhang et al. (2022) observe strong neural activation associated with self-selected choices, but no significant activation

[2]In Syam et al. (2008), consumers choose between customized and standardized products. In Nasiry and Popescu (2012) and Diecidue et al. (2012), consumers opt between forward purchase and spot-purchase. In Jiang et al. (2017), consumers decide between the old product and a new product with a new attribute.

associated with computer-selected choices. We conduct similar self-agency versus other-agency responsibility experiments, with more explicit economic implications. Specifically, we introduce a standard pricing framework and compare ERPs related to regret arising from proactive pricing by monopolistic sellers in the self-agency responsibility experiments and disappointment arising from passive pricing by perfectly competitive sellers in the other-agency responsibility experiments. Additionally, we differentiate between the emotions of regret and disappointment associated with underpricing and overpricing, that is, when the price is lower or higher than the consumer's willingness-to-pay. Our results reveal significant neural activation associated with both types of regret, as well as marginally significant activation related to underpricing disappointment, while no significant activation was observed for overpricing disappointment, suggesting that previous findings of insignificant neural activation associated with disappointment may have been due to a lack of distinction between different cases.

Our paper also contributes to the literature on event-related potentials (ERPs). Most studies focus on feedback-related negativity (FRN), an ERP component that occurs shortly after feedback, generally characterized as the second major negative deflection of the brain's electrophysiological response to feedback stimuli. FRN peaks approximately 200 to 400 milliseconds after an event (Yeung and Sanfey, 2004) and is most pronounced over the frontocentral region of the scalp (Hewig et al., 2007), reflecting activity from the anterior cingulate cortex during cognitive processing (Rodrigues et al., 2020, 2022). FRN is associated with reflective inhibition, mismatch detection, and response conflict (Folstein and Van Petten, 2008) and is one of the most widely studied ERP components in economic decision-making paradigms (Holroyd and Coles, 2002). Both Holroyd and Coles (2002) and Proudfit (2015) suggest that unexpected outcomes, particularly those deviating significantly from expectations, result in a heightened FRN response. P3, the third major positive deflection induced by stimuli, is another extensively studied ERP component. It originates primarily from the temporoparietal region (Rodrigues et al., 2022) and peaks between 300 and 600 milliseconds after stimulus onset, with the strongest activity observed in the vertex area (Yu et al., 2014; Hu and Mai, 2021). Neuroscience research indicates that P3 is associated with attentional processes and responses to unexpected stimuli (Riepl et al., 2016; Rodrigues et al., 2024). In economic decision-making contexts, P3 plays a crucial role in outcome evaluation and reward processing (Nieuwenhuis et al., 2005). Meadows et al. (2016) demonstrate that P3 is sensitive to task-relevant information, such as valence feedback, reward magnitude, and motivational states. Furthermore, Mayer et al. (2021) assert that various factors—including rewards, risks, and social dynamics—can broadly influence P3 amplitude. Our study presents group-average ERP waveforms that reveal distinct FRN and P3 peaks across different conditions. We show that the amplitudes of both FRN and P3 peaks are significantly affected by regret in the self-agency responsibility pricing experiment, and was significant at the 10

3 Materials and Methods

3.1 Participants

This experiment recruited 21 students from Zhengzhou University (6 females, 15 males, 23±2.6 years) as participants. None of the participants had taken any drugs that could affect the central nervous system. Their vision was either normal or corrected to normal, and all were right-handed with no history of neurological disorders. All participants signed informed consent forms before the experiment. The experimental design adhered to the Helsinki Declaration and was approved by the Ethics Committee of Zhengzhou University.

3.2 Experimental paradigm and procedure

We employed a standard pricing paradigm in which the consumer's willingness to pay is uncertain.[3] The seller sets a price based on prior beliefs about consumers' willingness to pay, without knowing the exact realized value. Subsequently, the consumer reveals their willingness to pay and determines whether to accept the predetermined price. Specifically, in each trial, the participant, acting as the seller, was presented with two options, "1" or "2", which represent selling prices set at 1 or 2 yuan, respectively. One of these options was chosen either actively by the participant or passively by the computer. Then, a computer simulated consumer reports its willingness-to-pay, also "1" or "2", and decides whether to purchase at the chosen price.

Two possible selling and purchasing prices result in four potential outcomes. If the consumer's willingness to pay (1 or 2 yuan) matches the set price, we denote these as Cases "11" and "22".

[3]See Li and Liu (2022), for an example.

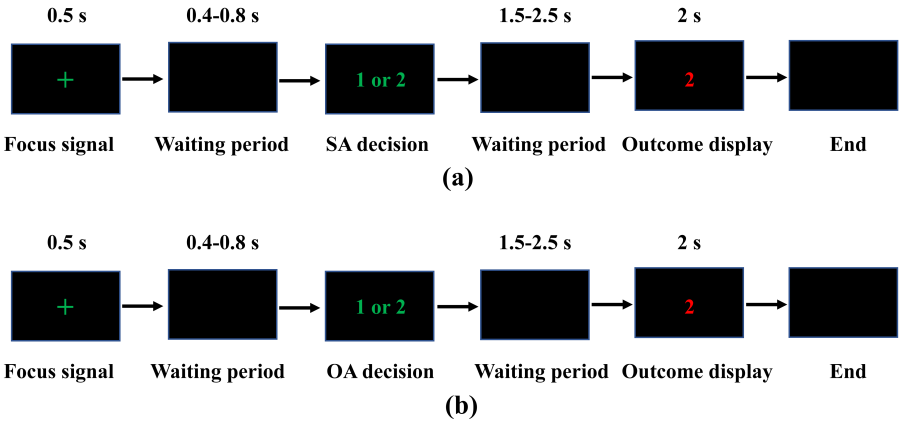


Figure 1: The sequence of events. This figure presents the sequence of events within a single trial for: (a) the self-agency responsibility pricing (SA) experiment, and (b) the other-agency responsibility pricing (OA) experiment.

In these cases, the good is sold without regret or disappointment. Conversely, if the consumer's willingness to pay is 2 yuan but the price is set at 1 yuan, this is defined as Case "12". In this situation, the good is sold at 1 yuan, but the participant realizes they could have earned 2 yuan by choosing the alternative. The negative emotions generated from this counterfactual thinking are termed "underpricing regret" and "underpricing disappointment" in self-agency and other-agency responsibility pricing experiments, respectively. For simplicity, we denote self-agency and other-agency responsibility pricing experiments as "SA" and "OA" experiments in the following analysis. Lastly, if the consumer's willingness to pay is 1 yuan but the price is set at 2 yuan, this is known as Case "21". Here, the good is not sold, and the participant realizes they could have earned 1 yuan by choosing the alternative. The corresponding negative emotions are termed "overpricing regret" and "overpricing disappointment" in the SA and OA experiments, respectively.

The SA experiment follows a specific procedural sequence, as illustrated in Figure 1a. Each trial begins with the display of a green "+" at the center of the screen, instructing participants to focus. This is followed by a variable waiting period of 0.4 to 0.8 seconds. Next, the options "1" and "2," representing price settings of 1 or 2 yuan, are presented for participants to choose. After the participant's pricing decision, there is an inter-trial interval lasting 1.5 to 2.5 seconds. Following this interval, the computer displays the outcome of the transaction for 2 seconds, concluding the trial. Each run consists of 50 trials, with 10 runs per experimental set, resulting in a total of 500 trials per participant.

The OA experiment follows the same stimulus paradigm as the above SA experiment, with one key difference: participants do not make pricing decisions, as illustrated in Figure 1b. Instead, the computer randomly sets the price. The number of experimental groups is the same as in the SA experiment.

The stimulus paradigm for this experiment was implemented using the Psychtoolbox in MATLAB. It is important to note that the computer-simulated consumer and seller choices were randomized, with equal probabilities of 1 and 2. Participants were informed that the computer's choices were entirely random but were not told the exact probabilities.

Before the experiment begins, participants were informed of the rules and instructions.[4] During the experiment, participants sat comfortably in a room shielded from electromagnetic interference, with their eyes at a horizontal level with the center of the computer monitor, approximately 100 centimeters away from the screen. Participants were well-rested and in good mental condition before the experiment. Their scalps were cleaned beforehand to minimize the impact of scalp dirt on the signals.

[4]The translated Chinese instructions for the SA experiment are: "This is a simulated pricing experiment. You act as a seller to sell one unit of a good. Selectable prices (1 yuan or 2 yuan) will appear on the screen. After you choose a price, the computer, acting as a consumer, will make an offer. The consumer's willingness to pay is either 1 yuan or 2 yuan. If the consumer's willingness to pay is 1 yuan, the good priced at 1 yuan will be sold, while the good priced at 2 yuan will not. Conversely, if the consumer's willingness to pay is 2 yuan, goods priced at both 1 yuan and 2 yuan will be sold. Your final payment is proportional to the income obtained from all transactions." Therefore, participants were encouraged to respond in a manner that would maximize their total income.

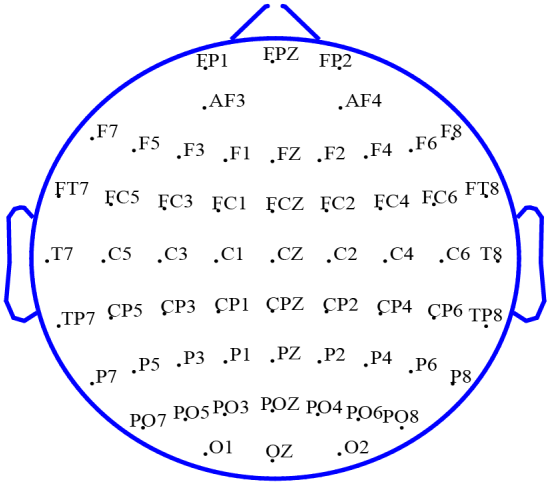


Figure 2: Electrode name and location distribution.

3.3 EEG data acquisition and processing

The participants' EEG signals were recorded using the NeuroScan 64-channel EEG system (Neuroscan Inc., Charlotte, NC, USA), following the extended International 10-20 system. The electrode names and positions on the cap are illustrated in Figure 2. The reference electrode was placed near Cz, and the ground electrode was near FPz. Throughout the experiment, electrode impedances were maintained below 5 kΩ, and 50Hz power line interference was removed during data recording. The data were sampled at a rate of 1000Hz.

Data preprocessing was conducted using the EEGLAB toolbox in MATLAB. First, the acquired EEG data were downsampled to 300 Hz. Then, channel locations were verified, and the data were bandpass filtered from 0.5 to 20 Hz. Bad segments and channels with poor data quality were removed, and the data were re-referenced. Independent Component Analysis (ICA) was employed to remove artifacts such as eye blinks and muscle activity.

The moment of outcome display is considered time 0. Data from 0.1 seconds before to 1 second after this point were collected, with trials exceeding a voltage threshold of ± 100 μV being excluded. The interval from -0.1 seconds to 0 serves as the baseline. All data were baseline corrected by subtracting the average activity during the baseline period from each sample.

As analyzed above, four possible cases can be identified: Cases "11," "22," "12," and "21." We consolidate the outcomes of Cases "11" and "22," which involve no regret or disappointment, into a single category referred to as the benchmark case. For each case of each participant, we overlaid all trials at the zero time point and calculated their average activity to generate the average ERP waveform. We then identified the FRN and P3 peak moments and calculated the corresponding peak amplitudes as the average activity from 10 ms before to 10 ms after each peak moment. Underpricing regret was represented by the negative difference between the FRN and P3 amplitudes of Case "12" and the benchmark case in the SA experiment, while underpricing disappointment corresponded to the same difference in the OA experiment. Similarly, overpricing regret was represented by the negative difference between the FRN and P3 amplitudes of Case "21" and the benchmark case in the SA experiment, while overpricing disappointment corresponded to the same differences in the OA experiment. We performed cluster-based tests on individual participants' ERP using the following parameters: a one-tailed dependent samples t-test, a time interval of [0, 0.8] seconds relative to onset, and 10,000 draws from the permutation distribution. We also plotted the scalp potential spatial distribution at the FRN and P3 peaks. The entire EEG data acquisition and processing process is illustrated in Figure 3.

3.4 Emotion scale recordings

We also recorded participants' responses to a traditional Likert-type emotion scale as an alternative method to assess their feelings of regret and disappointment. Participants were instructed to use a

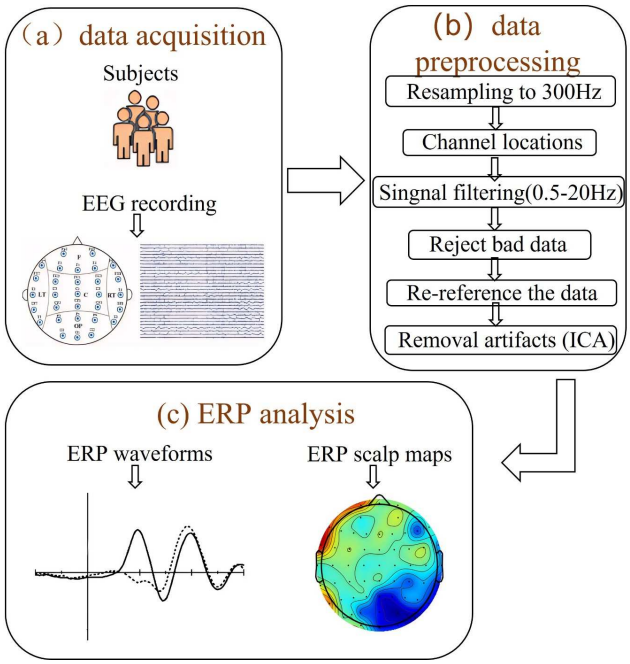


Figure 3: EEG data acquisition and processing process. The participants' EEG signals were recorded using the NeuroScan 64-channel EEG system (Neuroscan Inc., Charlotte, NC, USA), following the extended International 10-20 system.

10-point scale to evaluate their emotions for Cases "11", "22", "12", and "21".[5] We still regard Cases "11" and "22" as the benchmark case. Each participant's underpricing regret or disappointment is measured as the negative difference between their emotion scale for Case "12" and the benchmark case. Similarly, each participant's overpricing regret or disappointment is measured as the negative difference between their emotion scale for Case "21" and the benchmark case.

3.5 Theoretical hypothesis and regression tests about participants' pricing decisions

Focusing on the SA experiments, we used the negative differences in participants' FRN amplitudes between Case "12" and the benchmark case, and between Case "21" and the benchmark case, as representative variables for underpricing and overpricing regret. We then tested whether these variables are determinants in explaining participants' pricing behavior and whether their effects align with theoretical predictions.

As demonstrated by Li and Liu (2022), if sellers anticipate experiencing a higher degree of underpricing or overpricing regret, they tend to avoid these scenarios. Consequently, they may set a higher or lower price ex ante. Based on these findings, we derived the first hypothesis regarding the effects of individual levels of underpricing and overpricing regret on pricing behaviors.

Hypothesis 1: The higher the level of underpricing /overpricing regret, the more/less likely the participants are to set a high price.

We tested this hypothesis using the following linear regression function:

$$P(\text{Case}_{22\&21})_i = \alpha + \beta_1 UR_{FRN,i} + \beta_2 OR_{FRN,i} + \epsilon_i. \tag{1}$$

where i indexes the participant, $P(\text{Case}_{22\&21})_i$ represents participant i's probability of setting the price at 2 yuan (i.e., setting a high price), $UR_{FRN,i}$ and $OR_{FRN,i}$ are participant i's FRN measures of underpricing and overpricing regret (i.e., the negative differences in participant i's FRN amplitudes between Case "12" and the benchmark, and between Case "21" and the benchmark, respectively), and ϵ_i is the random term.

Historical experience may also influence the predictive power of participants' individual levels of regret. Repeated occurrences of underpricing and overpricing cases (i.e., Cases "12" and "21")

[5]The translated Chinese instructions are as follows: "The emotion scale is divided into 10 levels, ranging from 1 to 10, where 5 represents calmness. Negative emotions increase as the rating decreases from 5 to 1, and positive emotions increase from 5 to 10. Please select your emotion scale when the selling price was 1 or 2 and the willingness-to-pay was 1 or 2."

increase the salience of the associated underpricing and overpricing regret, potentially leading participants to adjust their prices to avoid these negative emotions in the future. For participants with higher levels of underpricing and overpricing regret, the salience of these emotions is expected to have a greater impact. Therefore, we derived the second hypothesis regarding the interaction effect between individual levels of underpricing and overpricing regret and the historical occurrences of underpricing and overpricing cases on pricing behaviors.

Hypothesis 2: The higher the level of underpricing /overpricing regret, the greater the positive/negative impact of historical occurrences of underpricing and overpricing cases on participants' probability of setting a high price.

We test this hypothesis using the following logit regression function:

$$\begin{aligned}\log\left(\frac{P(\text{Case}_{22\&21})_{it}}{1-P(\text{Case}_{22\&21})_{it}}\right) = \alpha &+ \beta_1 UR_{FRN,i} \times Case12Count_{it} \\ &+ \beta_2 OR_{FRN,i} \times Case21Count_{it} + \beta_3 UR_{FRN,i} + \beta_4 OR_{FRN,i} \\ &+ \beta_5 Case12Count_{it} + \beta_6 Case21Count_{it} + \epsilon_{it}.\end{aligned} \tag{2}$$

where i indexes the participant, t indexes the trial, $P(\text{Case}_{22\&21})_{it}$ represents the probability of setting the price at 2 yuan for participant i in trial t (i.e. setting a high price), $UR_{FRN,i}$ and $OR_{FRN,i}$ are participant i's FRN measures of underpricing and overpricing regret (i.e. the negative differences in participant i's FRN amplitudes between Case "12" and the benchmark, and between Case "21" and the benchmark, respectively), $Case12Count_{it}$ and $Case21Count_{it}$ are the fractions of Cases "12" and "21" in participant i's previous 10 trials before trial t (i.e., historical occurrences of underpricing and overpricing cases), and ϵ_{it} is the random term.

4 Results

4.1 ERP results of regret and disappointment

4.1.1 Average ERP waveforms

We first analyzed the ERP results from the SA experiment. Figure 4a and 4b illustrate the group-average ERP waveforms recorded at the frontal lobe for Case "12" (with underpricing regret) and Case "21" (with overpricing regret), compared to the benchmark case without regret. In Figure 4a, the FRN component for Case "12" had an amplitude of -0.667 μV and a latency of 326ms, whereas the corresponding values for the benchmark were 0.326μV and 248ms. Similarly, the P3 component for Case "12" had an amplitude of 0.792μV and a latency of 356ms, while the benchmark values were 1.398μV and 316ms. These differences were statistically significant ($p < 0.05$, cluster-corrected), indicating a distinct impact of underpricing regret on brain activity. In Figure 4b, the FRN amplitude for Case "21" was -0.594 μV, with a latency of 268ms, compared to 0.326μV and 248ms for the benchmark. The P3 component in this case had an amplitude of 2.407μV and a latency of 364ms, compared to the benchmark's 1.398μV and 316ms. Again, the differences in amplitudes were statistically significant ($p < 0.05$, cluster-corrected), suggesting that overpricing regret also significantly affected participants' neural responses.

For the OA experiment, Figure 4c and 4d present ERP waveforms for Case "12" (with underpricing disappointment) and Case "21" (with overpricing disappointment). In Case "12," the FRN amplitude was -0.948 μV, with a latency of 288ms, compared to benchmark values of -0.237 μV and 312ms. The P3 amplitude in this case was -0.764 μV, with a latency of 324ms, compared to -0.213 μV and 332ms for the benchmark. These differences were statistically significant at the 10% level but not at the 5% level ($0.05 < p < 0.1$, cluster-corrected), implying a lesser impact of underpricing disappointment. For Case "21," the FRN amplitude was -0.415 μV, with a latency of 344ms, compared to -0.237 μV and 312ms for the benchmark. The P3 amplitude was -0.015 μV, with a latency of 408ms, compared to -0.213 μV and 332ms for the benchmark. No statistically significant differences were found ($p > 0.1$, cluster-corrected). Notably, in Figure 4c, the P2 component for Case "21" showed an amplitude of 2.066μV with a latency of 236ms, compared to 0.915μV and 204ms for the benchmark. These differences in amplitudes were statistically significant ($p < 0.05$, cluster-corrected).

4.2 Scalp potential spatial of ERPs

We plotted the scalp potential spatial distribution of ERPs at the FRN and P3 peaks for the SA experiment, as shown in Figure 5a and 5b. In Figure 5a, the FRN components for Case "12" (with underpricing regret) and the benchmark case (for comparison) were primarily distributed in the

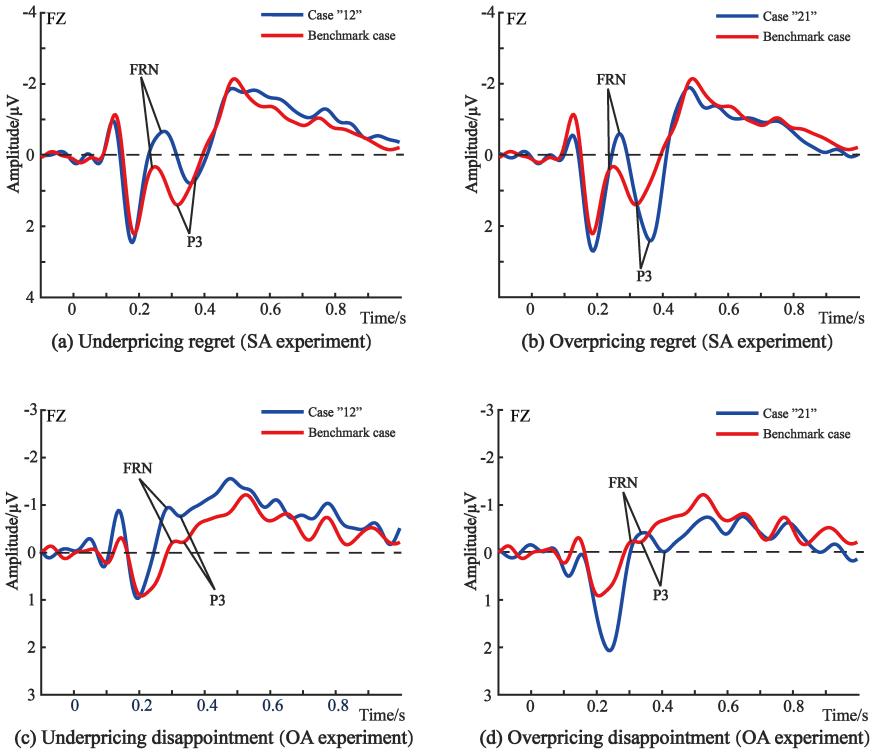


Figure 4: ERP analysis results. This figure compares the group-average ERP waveforms at the frontal lobe to illustrate neural responses for: (a) underpricing regret (Case "12" vs. the benchmark case in the SA experiment); (b) overpricing regret (Case "21" vs. the benchmark case in the SA experiment); (c) underpricing disappointment (Case "12" vs. the benchmark case in the OA experiment); and (d) overpricing disappointment (Case "21" vs. the benchmark case in the OA experiment). The vertical axis represents amplitude, indicating the voltage of the EEG signal, with negative values plotted upwards and positive values downwards as per conventional EEG representation. The horizontal axis represents time, where 0 marks the moment of outcome display. The benchmark case refers to the consolidated ERP waveforms from Cases "11" and "22".

central frontal region, with more negative activation linked to underpricing regret mainly observed in the prefrontal area. The P3 components were predominantly distributed in the central parietal region, with the difference concentrated in the anterior parietal and posterior frontal regions, indicating weaker activation associated with underpricing regret. In Figure 5b, for Case "21" (with overpricing regret) compared to the benchmark case, the FRN components were primarily distributed in the frontal region, with more negative activation linked to overpricing regret mainly in the prefrontal area. The P3 components were distributed across the central parietal region, with differences primarily observed in the anterior frontal area, indicating stronger activation related to overpricing regret.

The scalp potential spatial distribution results for the OA experiment are shown in Figure 5c and 5d. In Figure 5c, the FRN components for Case "12" (with underpricing disappointment) and the benchmark case were primarily distributed in the central frontal region, with more negative activation tied to underpricing disappointment mainly located in the frontal area. The P3 components were primarily distributed in the central posterior parietal region, with the differences mainly in the frontal area, indicating weaker activation in the case with underpricing disappointment compared to the benchmark without disappointment. In Figure 5d, for Case "21" (with overpricing disappointment) compared to the benchmark case, the FRN components were primarily distributed in the frontal region, with differences centered in the central frontal area, indicating more negative activation linked to overpricing disappointment. The P3 components were distributed in the central posterior parietal region, with no significant differences between the two cases.

In summary, we observed significant neural responses linked to both types of regret in the SA experiment, weaker but still marginally significant neural responses to underpricing disappointment, and insignificant neural responses to overpricing disappointment in the OA experiment. Specifically,

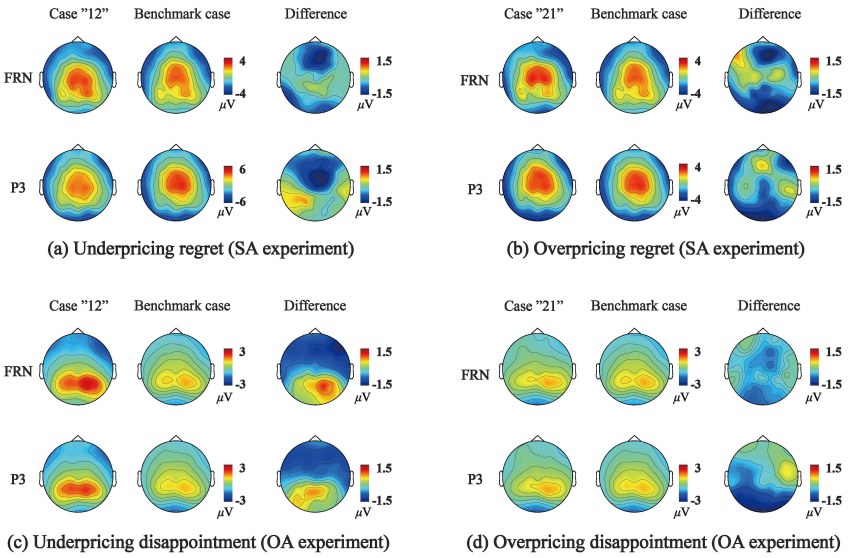


Figure 5: Scalp potential spatial distribution results. The figure compares the scalp potential spatial distribution of ERPs at the FRN and P3 peaks to illustrate neural responses for: (a) underpricing regret (Case "12" vs. the benchmark in the SA experiment); (b) overpricing regret (Case "21" vs. the benchmark in the SA experiment); (c) underpricing disappointment (Case "12" vs. the benchmark in the OA experiment); and (d) overpricing disappointment (Case "21" vs. the benchmark in the OA experiment). Warm-colored areas represent brain regions with positive voltage, while cool-colored areas represent regions with negative voltage. The voltage unit is μV. The benchmark case refers to the consolidated scalp potential spatial distribution for Cases "11" and "22".

in the SA experiment, FRN amplitudes for Cases "12" (with underpricing regret) and "21" (with overpricing regret) were both larger compared to the benchmark case, indicating heightened conflict between participants' expectations and the acceptance outcomes. However, the P3 amplitude in Case "12" was lower than in the benchmark case, whereas the P3 amplitude in Case "21" was higher. This pattern may reflect differences in attention or outcome evaluation between the two pricing conditions, although the underlying psychological process cannot be determined from the ERP data alone. Our findings largely align with those of Giorgetta et al. (2013) and Zhang et al. (2022). However, we differentiated between underpricing and overpricing disappointment and found marginally significant neural activation associated with underpricing disappointment, whereas they found only insignificant neural activation when consolidating different types of disappointment. Furthermore, we successfully identified a distinct FRN component—specifically, the second major negative peak induced by outcome display. In contrast, Zhang et al. (2022) were unable to identify this component and instead used the peak amplitude of the difference wave as an alternative measure. Finally, we provided complete topographical maps of neural activation at the FRN and P3 peaks, highlighting the brain regions where the differences among various cases were most pronounced.

4.3 Individual ERP results of regret and disappointment

4.3.1 Heterogeneity in individual ERP waveforms

Unlike the previous subsection, which focuses on group characteristics of ERP results related to regret and disappointment, this subsection explores individual-level results. In Table 1, we presented summary statistics of participants' FRN and P3 amplitudes across different cases in both the SA and OA experiments, demonstrating the heterogeneity in individual brain activity when experiencing regret or disappointment.[6]

[6]To more intuitively illustrate individual differences, we plotted and compared the ERP waveforms of two participants, S1 and S2, showing their neural responses to underpricing and overpricing regret and disappointment in the Appendix.

Table 1: Summary statistics of participants' FRN and P3 magnitudes

	Count	Mean	SD	p25	p50	p75
(a) The SA experiment						
Case12 FRN_i	21	-0.9974	1.8857	-2.1300	-0.7704	-0.1250
Case12 $P3_i$	21	-0.6027	2.1141	-1.5033	0.0059	0.5731
Case21 FRN_i	21	-0.8980	1.6839	-1.9072	-1.2887	-0.1127
Case21 $P3_i$	21	0.9918	1.9350	0.1557	1.1985	1.8849
Benchmark FRN_i	21	0.3429	2.0736	-0.9480	0.0420	1.6761
Benchmark $P3_i$	21	1.3795	2.4383	0.0570	1.0765	2.6496
(b) The OA experiment						
Case12 FRN_i	21	-0.7186	1.3262	-1.8531	-0.1460	0.1769
Case12 $P3_i$	21	-0.5528	1.2608	-1.3518	-0.4200	0.4633
Case21 FRN_i	21	-0.1976	1.1467	-0.7960	-0.2885	0.4480
Case21 $P3_i$	21	0.1962	1.2520	-0.1655	0.2621	0.6481
Benchmark FRN_i	21	-0.2126	1.4871	-1.4009	-0.0390	0.5022
Benchmark $P3_i$	21	-0.2200	1.2974	-1.2076	-0.2576	0.6813

Notes. This table reports summary statistics of participants' FRN and P3 amplitudes, as denoted in variable names: "FRN" for feedback-related negativity, "P3" for the P3 component, "Case12" for Case "12", "Case21" for Case "21", and "benchmark" for the benchmark case. Results are presented for: (a) the SA experiment, and (b) the OA experiment. The sample consists of 21 participants from our experiments.

4.3.2 Relationship between individual ERP and emotion scale measures

We then examined whether ERP amplitudes could serve as electrophysiological proxies for individual differences in regret and disappointment by testing their associations with emotion-scale measures.To represent individual levels of regret or disappointment, we used the negative difference in ERP amplitudes or emotion scales between the specific case with corresponding counterfactual thinking and the benchmark case. For example, the ERP measures of underpricing regret were calculated as the negative differences in FRN and P3 amplitudes between Case "12" and the benchmark in the SA experiments, while the corresponding emotion scale measure was calculated as the negative difference in emotion scale between the same cases.

We performed linear regressions of the emotion scale measures on the corresponding ERP measures. Table 2 presents the regression results for underpricing and overpricing regret. For underpricing regret, the coefficient on the FRN measure was consistently positive and statistically significant, regardless of whether the P3 measure was included (column (3)) or not (column (1)). For overpricing regret, the coefficient on the FRN measure was positive and statistically significant at the 10% level only when the P3 measure was excluded (column (1)). However, the coefficient on the P3 measure was never statistically significant. Regarding the goodness of fit of the regression models, columns (1) (using only the FRN measure as the explanatory variable) and (3) (using both the FRN and P3 measures as explanatory variables) had relatively high adjusted R2 values. We then conducted an F-test for model comparison. The nested F-statistics comparing columns (1) and (3) were 0.1022 and 0.1226 for underpricing and overpricing regret, respectively, neither of which were statistically significant. Therefore, we conclude that the FRN measures are more suitable representative variables for participants' underpricing and overpricing regret, as indicated by their significant correlation with the emotion scale measures.

Table 3 presented the regression results for underpricing and overpricing disappointment. For underpricing disappointment, the coefficients on the FRN, P3, and P2 measures were negative and statistically significant when only one of them was included (columns (1)–(3)). For overpricing disappointment, none of the coefficients were statistically significant. Regarding the goodness of fit of the regression models for underpricing disappointment, columns (1) and (5) had relatively high adjusted R2 values. The nested F-statistic comparing these two columns was 1.2212, which was not statistically significant. In contrast, the adjusted R2 values of the regression models for overpricing disappointment were consistently below zero. Considering the coefficient and adjusted R2 results comprehensively, we infer that the FRN measure remains a suitable representative variable for underpricing disappointment, while its representativeness for overpricing disappointment is questionable. The scatterplots in Figure 6 illustrate the relationships between the FRN and emotion scale measures for underpricing and overpricing regret and disappointment.

4.4 Correlation between underpricing and overpricing regret and disappointment

We then analyzed the correlation between participants' regret and disappointment as measured by FRN amplitudes or emotion scales. The results are presented in Table 4. For the FRN measures, a positive and statistically significant correlation was found only between underpricing and

Table 2: Emotion scale and ERP measures of underpricing and overpricing regret

	(1)	(2)	(3)
(a) Underpricing regret			
		UR Emotion$_i$	
UR FRN$_i$	-0.6308***		-0.6252***
	(0.1535)		(0.1573)
UR P3$_i$		0.1075	-0.0772
		(0.1866)	(0.1403)
Observation		21	
Adjusted R^2	0.0978	0.0063	0.0553
(b) Overpricing regret			
		OR Emotion$_i$	
OR FRN$_i$	-0.4024*		-0.5070
	(0.2260)		(0.3598)
OR P3$_i$		0.2191	-0.1189
		(0.2064)	(0.3131)
Observation		21	
Adjusted R^2	0.0978	0.0063	0.0553

Notes. This table presents the regression results of emotion scale measures on corresponding ERP measures for: (a) underpricing regret, and (b) overpricing regret. The emotion scale measures, UR Emotion$_i$ and OR Emotion$_i$, were calculated as the negative differences between the emotion scales of Case "12" and the benchmark, and Case "21" and the benchmark, respectively, in the SA experiment. The ERP measures UR FRN$_i$, OR FRN$_i$, UR P3$_i$, and OR P3$_i$ were calculated as the negative differences in FRN and P3 amplitudes between the same cases. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

overpricing regret ($r = 0.7194$, $p < 0.0001$). For the emotion scale measures, significant positive correlations were observed between underpricing and overpricing regret ($r = 0.6160$, $p = 0.0029$), as well as between underpricing and overpricing disappointment ($r = 0.8471$, $p < 0.0001$).

In summary, we verified the heterogeneity in participants' ERP waveforms and the feasibility of measuring individual levels of regret and underpricing disappointment through negative differences in FRN amplitudes across different cases. Specifically, underpricing and overpricing regret are represented by the negative differences in FRN and P3 amplitudes between Case "12" and the benchmark, and Case "21" and the benchmark, respectively, in the SA experiment. Similarly, underpricing and overpricing disappointment are represented by the same negative differences in the OA experiment. Using linear regression, we showed that the FRN measures of the two types of regret and underpricing disappointment were significantly correlated with their corresponding emotion scale measures.

These findings provide preliminary support for using FRN differences as proxy measures of individual underpricing and overpricing regret. In the next subsection, we used these regret-related FRN measures as explanatory variables in regression models to test their predictive power regarding participants' pricing decisions.

4.5 Regression results about pricing decisions

4.5.1 The effects of underpricing and overpricing regret on the participants' probability to set a high price

We first tested the direct effects of underpricing and overpricing regret on participants' pricing behaviors using linear regression. As stated in the Materials and Methods Section, Equation 1 represents the regression function, where the regret-related FRN measures constructed above were used as representative variables for underpricing and overpricing regret. Table 5 summarizes the results. The coefficient for underpricing regret ($UR_{FRN,i}$) was negative and statistically significant, regardless of whether overpricing regret ($OR_{FRN,i}$) was included (column (3)) or not (column (1)). In contrast, the coefficient for overpricing regret ($OR_{FRN,i}$) was never statistically significant. We found that participants with higher underpricing regret were even more inclined to set a low price, which could lead to an unfavorable underpricing case, rather than setting a high price to avoid it. This result clearly contradicts Hypothesis 1, which was derived in the Materials and Methods Section from Li and Liu (2022). However, it might be due to reverse causality—i.e., the frequent occurrence of underpricing cases amplifies participants' negative emotions associated with them. To ensure the robustness of our tests, we next focused on the interaction effects between regret and the historical occurrences of underpricing and overpricing cases in the previous 10 trials.

Table 3: Emotion scale and ERP measures of underpricing and overpricing disappointment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(a) Underpricing disappointment							
				UD Emotion$_i$			
UD FRN$_i$	-0.7150***			0.7029	0.4357		0.5856
	(0.2227)			(0.4698)	(0.3312)		(0.4706)
UD P3$_i$		-0.6603**		-0.0146		-0.2201	0.2404
		(0.2484)		(0.4942)		(0.3860)	(0.5330)
UD P2$_i$			-0.8696***		-0.4663	-0.6666	-0.5493
			(0.2801)		(0.4118)	(0.4562)	(0.4596)
Observation				21			
Adjusted R^2	0.3175	0.2327	0.3017	0.2797	0.3275	0.2760	0.2964
(b) Overpricing disappointment							
				UD Emotion$_i$			
OD FRN$_i$	0.0509			0.0243	0.0636		0.0568
	(0.3231)			(0.3356)	(0.3931)		(0.4023)
OD P3$_i$		-0.1399		-0.1359		-0.1488	-0.1471
		(0.2944)		(0.3074)		(0.3159)	(0.3240)
OD P2$_i$			-0.0089		0.0203	0.0299	0.0556
			(0.2769)		(0.3367)	(0.2944)	(0.3530)
Observation				21			
Adjusted R^2	0.3175	0.2327	0.3017	0.2797	0.3275	0.2760	0.2964

Notes. This table presents the regression results of emotion scale measures on corresponding ERP measures for: (a) underpricing disappointment, and (b) overpricing disappointment. The emotion scale measures, UD Emotion$_i$ and OD Emotion$_i$, were calculated as the negative differences between the emotion scales of Case "12" and the benchmark, and Case "21" and the benchmark, respectively, in the OA experiment. The ERP measures UD FRN$_i$, OD FRN$_i$, UD P3$_i$, and OD P3$_i$ were calculated as the negative differences in FRN and P3 amplitudes between the same cases. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Correlation matrix of participants' underpricing and overpricing regret and disappointment

(a) FRN measures				
	UR FRN$_i$	OR FRN$_i$	UD FRN$_i$	OD FRN$_i$
UR FRN$_i$	–			
OR FRN$_i$	0.7194***	–		
UD FRN$_i$	0.2111	0.2700	–	
OD FRN$_i$	-0.1147	-0.1269	0.1236	–
(b) Emotion scale measures				
	UR Emotion$_i$	OR Emotion$_i$	UD Emotion$_i$	OD Emotion$_i$
UR Emotion$_i$	–			
OR Emotion$_i$	0.6160***	–		
UD Emotion$_i$	-0.0296	-0.3975	–	
OD Emotion$_i$	0.0127	-0.2976	0.8471***	–

Note. This table presents the correlations between underpricing and overpricing regret ("UR" and "OR") and underpricing and overpricing disappointment ("UD" and "OD"), represented by: (a) FRN measures ("FRN"), and (b) emotion scale measures ("Emotion"). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.5.2 The interaction effects between regret and historical occurrences of underpricing and overpricing cases

We then tested whether higher levels of underpricing and overpricing regret amplify the effects of the salience of historical occurrences of underpricing and overpricing cases, making participants more inclined to avoid such cases. Table 6 presents the results of the logit regression from Equation 2 in the Materials and Methods Section, where FRN measures were still used as representative variables for underpricing and overpricing regret. The interaction effect between historical underpricing occurrences and underpricing regret was statistically insignificant. In contrast, the interaction effect between historical overpricing occurrences and overpricing regret was positive and statistically significant. This implies that participants with higher overpricing regret were more likely to set a high price again after observing overpricing cases, which contradicts Hypothesis 2. Notably, the statistically significant results only occurred when FRN measures were used as representative variables for underpricing and overpricing regret.[7]

In summary, our results contradict the theoretical hypotheses. Linear regression shows that participants' probabilities of setting a high price are negatively correlated with their levels of underpricing regret. Logit regression demonstrates that a higher level of overpricing regret increases

[7]See the Appendix for the regression results when using emotion scale measures as representative variables. The coefficients for both interaction terms were statistically insignificant.

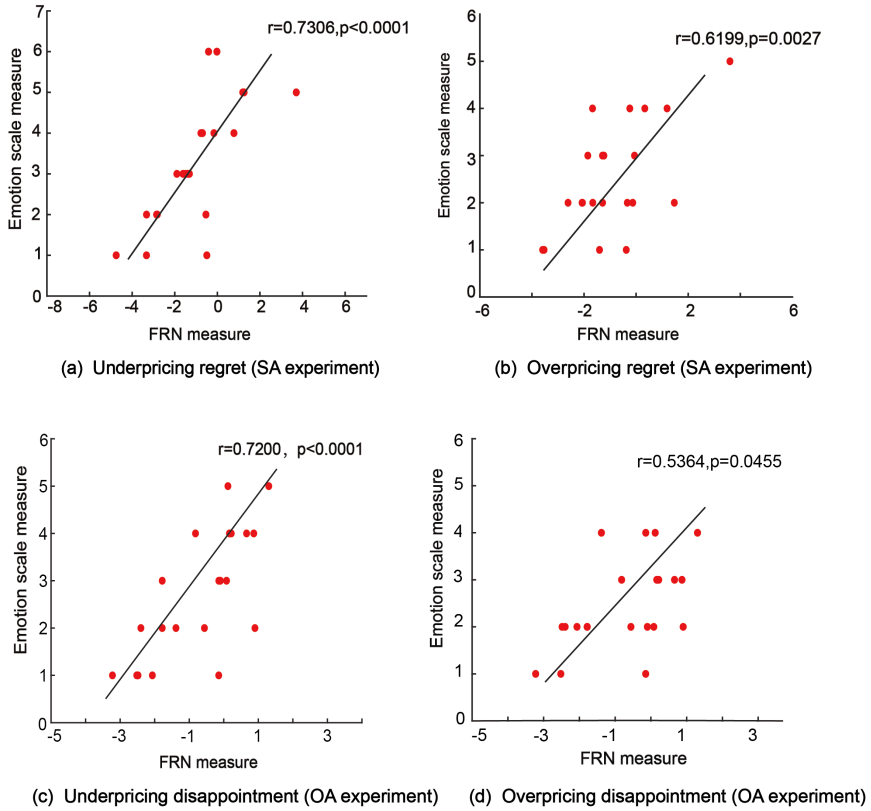


Figure 6: Scatterplots of emotion scale measures against FRN measures. The figure shows the relationships between the FRN and emotion scale measures for (a) underpricing regret (Case "12" vs. the benchmark in the SA experiment); (b) overpricing regret (Case "21" vs. the benchmark in the SA experiment); (c) underpricing disappointment (Case "12" vs. the benchmark in the OA experiment); and (d) overpricing disappointment (Case "21" vs. the benchmark in the OA experiment). The x-axis represents the FRN measures (in μV), while the y-axis represents the corresponding emotion scale measures. Each point represents an individual participant.

the likelihood that historical occurrences of overpricing cases will lead participants to set a high price again. Thus, participants do not "rationally" avoid regret-related negative emotions.

There are several possible reasons for this. Firstly, individuals may hold the belief that "this time will be different," expecting that repeating the behavior will lead to a different outcome. Secondly, the negative emotions brought on by regret may actually strengthen the memory of the behavior that caused the regret, leading individuals to unconsciously repeat the same behavior. Additionally, people may believe that achieving success in the same situation can "make up" for their previous failure. The precise reasons for the observed results still require further investigation. However, our findings suggest potential issues with the regret theory in behavioral economics, which treats regret as disutility and predicts individual behavior by maximizing the regret-adjusted utility function.

5 Conclusion

Our paper introduces neuroscientific methods into the classical pricing framework, distinguishing between a self-agency responsibility experiment, where participants experience regret, and an other-agency responsibility experiment, where participants experience disappointment. We recorded participants' ERP waveforms and scalp potential spatial distributions in response to underpricing and overpricing regret and disappointment, comparing them to those in the benchmark case without regret or disappointment. We found significant neural responses to both types of regret, a marginally significant neural response to underpricing disappointment, while the neural response to overpricing disappointment was insignificant. Additionally, we demonstrated heterogeneity in participants' ERP waveforms and the feasibility of measuring individual levels of regret and underpricing disappointment using negative differences in FRN amplitudes across different cases.

Table 5: Effects of underpricing and overpricing regret on pricing behaviors

	(1)	(2)	(3)
$P(\text{Case}_{22\&21})_i$			
$UR_{FRN,i}$	-0.0279**		-0.0444***
	(0.0107)		(0.0149)
$OR_{FRN,i}$		-0.0101	0.0257
		(0.0138)	(0.0167)
Observation		21	
Adjusted R^2	0.2234	-0.0240	0.2756

Notes. This table presents the linear regression results for participants' probability of setting the price at 2 yuan, $P(\text{Case}_{22\&21})_i$, regressed on their FRN measures of underpricing and overpricing regret, $UR_{FRN,i}$ and $OR_{FRN,i}$. The $UR_{FRN,i}$ and $OR_{FRN,i}$ values were calculated as the negative differences in participant i's FRN amplitudes between Case "12" and the benchmark, and between Case "21" and the benchmark, respectively. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Interaction effects between regret and historical occurrences of underpricing and overpricing cases

	(1)	(2)	(3)
$P(\text{Case}_{22\&21})_{it}$			
$Case12Count_{it} \times UR_{FRN,i}$	-0.0675		0.0515
	(0.0735)		(0.0768)
$Case21Count_{it} \times OR_{FRN,i}$		0.3587***	0.3336***
		(0.0749)	(0.0789)
$UR_{FRN,i}$	0.0527**		0.1184***
	(0.0210)		(0.0247)
$OR_{FRN,i}$		-0.1299***	-0.2292***
		(0.0219)	(0.0262)
$Case12Count_{it}$	-1.1288***		-0.6438***
	(0.1511)		(0.1644)
$Case21Count_{it}$		1.0682***	0.6742***
		(0.1554)	(0.1697)
Observation		9980	
Adjusted R^2	0.0105	0.0142	0.0235

Notes. This table presents the logit regression results for participants' probability of setting the price at 2 yuan, $P(\text{Case}_{22\&21})_{it}$, regressed on FRN measures of underpricing and overpricing regret ($UR_{FRN,i}$, $OR_{FRN,i}$), historical occurrences of underpricing and overpricing cases ($Case12Count_{it}$, $Case21Count_{it}$), and their interaction terms. $UR_{FRN,i}$ and $OR_{FRN,i}$ were calculated as the negative differences in participant i's FRN amplitudes between Case "12" and the benchmark, and between Case "21" and the benchmark, respectively. $Case12Count_{it}$ and $Case21Count_{it}$ were calculated as the fractions of Cases "12" and "21" in participant i's previous 10 trials before trial t. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

We also used the constructed FRN measures as representative variables for underpricing and overpricing regret to study their effects on participants' pricing decisions through regression analysis. Our findings indicate that participants with higher underpricing regret are more likely to set a low price. Additionally, higher overpricing regret increases participants' tendency to set a high price again after observing overpricing case occurrences. Both results contradict the conventional assumption in behavioral economics that agents strategically make decisions to avoid disutility from regret. Therefore, our paper provides experimental evidence for potential cognitive processes overlooked by existing behavioral economic theories, such as hope for a different outcome and negative emotion reinforcement. This also opens up opportunities for future research to investigate the precise reasons behind these results, and to modify theoretical models accordingly.

A Appendix

Table 7: Interaction effects between emotion scale-measured regret and historical occurrences of underpricing and overpricing cases

	(1)	(2)	(3)
$P(\text{Case}_{22\&21})_{it}$			
$Case12Count_{it} \times UR_{Emotion,i}$	0.0209		0.0239
	(0.7940)		(0.0842)
$Case21Count_{it} \times OR_{Emotion,i}$		-0.0843	-0.0984
		(0.0806)	(0.0832)
$UR_{Emotion,i}$	0.0196		0.0393
	(0.4205)		(0.0257)
$OR_{Emotion,i}$		0.0092	-0.0153
		(0.0211)	(0.0241)
$Case12Count_{it}$	-1.3109***		-0.8921***
	(0.3425)		(0.3618)
$Case21Count_{it}$		1.8319***	1.4826***
		(0.3034)	(0.4194)
Observation		9980	
Adjusted R^2	0.0098	0.0109	0.0147

Notes. This table presents the logit regression results for participants' probability of setting the price at 2 yuan, $P(\text{Case}_{22\&21})_{it}$, regressed on emotion scale measures of underpricing and overpricing regret ($UR_{Emotion,i}$, $OR_{Emotion,i}$), historical occurrences of underpricing and overpricing cases ($Case12Count_{it}$, $Case21Count_{it}$), and their interaction terms. $UR_{Emotion,i}$ and $OR_{Emotion,i}$ were calculated as the negative differences in participant i's emotion scales between Case "12" and the benchmark, and between Case "21" and the benchmark, respectively. $Case12Count_{it}$ and $Case21Count_{it}$ were calculated as the fractions of Cases "12" and "21" in participant i's previous 10 trials before trial t. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

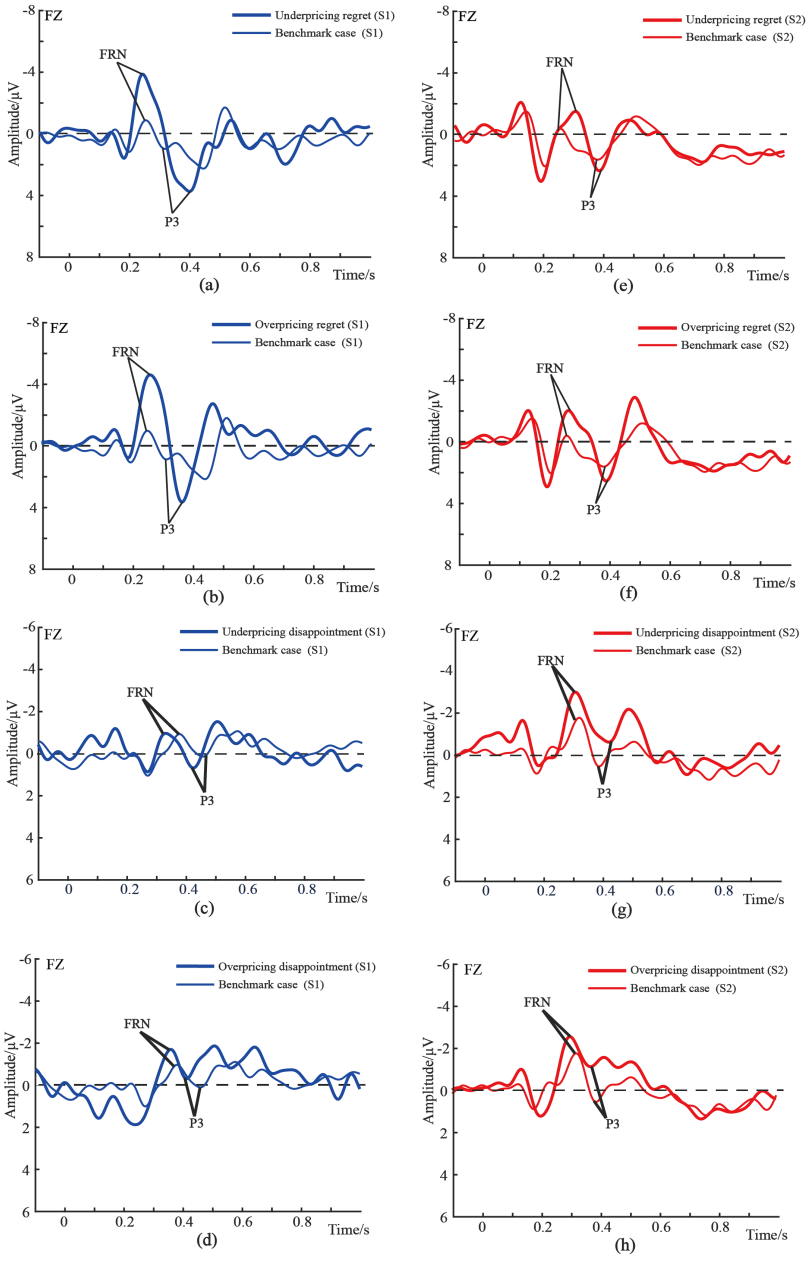


Figure 7: Individual ERP results for SA experiment and OA experiment. This figure compares the ERP waveforms associated with: (a) the underpricing regret of S1; (b) the overpricing regret of S1; (c) the underpricing disappointment of S1; (d) the overpricing disappointment of S2. (e) the underpricing regret of S2; (f) the overpricing regret of S2; (g) the underpricing disappointment of S2; (h) the overpricing disappointment of S2.

Author contributions

Tongyuan Shen and Yuxia Hu conceived the experiments. Xingke Ma and Lipeng Zhang conducted the experiments. Tongyuan Shen, Chenshuo Wang, and Lipeng Zhang analysed the results. Tongyuan Shen, Chenshuo Wang, and Xingke Ma wrote and reviewed the manuscript. All authors reviewed and approved the final manuscript.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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Conflict of interest

No competing interest is declared.

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