Predicting Aggregate Choice from Preconscious Processing

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Introduction

Predicting behavior is understood to be difficult. However, there is economic incentive to predict consumers' choices at a market level and this provides a clearly defined problem for investigation of the mechanisms of choice. Previous research has shown that forecasting group choice is possible, but whether the determining process of decision-making happens in the conscious or unconscious realm is yet to be explored.

Based on commercial transactions on the internet, large scale, market-level data became available for researchers to examine the relationship between individual brain activity and aggregate choice of the group. In order to test whether neural and affective responses were capable of predicting decisions of microloan requests at both individual and market level, Genevsky and Knutson set up a neuroimaging study that extracted neural activity of subjects as they went through the online microlending process recreated by the researchers (2015). They hypothesized that subjects' activity in circuits that involve anticipatory affect (i.e. nucleus accumbens (NAcc) and anterior insula (AIns)) could predict Internet loan-request success. They found that NAcc exhibited activity showed a significant and positive association with Internet lending rates. Moreover, NAcc activitiy predicted the results of Internet loan-request during the phase where photographs of borrowers were shown, which was prior to the decision phase. In addition, among choice, affect, and neural variables measured in this study, only NAcc activity and positive arousal had significant association with Internet lending rate. These findings suggested that brain data, specifically NAcc, is effective in forecasting aggregate choice, especially the Internet loan-request success.

The traditional idea that future choices were best predicted by individual's previous choices was contradicted by recent evidence suggesting that neural activity might complement

behavioral methods in predicting future choices. Based on this context, Genevsky et al. saw the gap that although brain data collected using fMRI could predict individual choice, the value of predicting aggregate choice using this method needed to be further explored (2017). To test the feasibility of both predicting individual choice and forecasting aggregate choice through examining neural activity, Genevsky et al. asked participants to look at 36 real crowdfunding projects when they are in fMRI, and make a decision on whether to fund these projects, weeks before the final market choice was made (2017). After scanning, participants were asked to rate how much they liked each project, rate their own affective responses to each project, and make prediction on how likely each project would reach its funding goal on the crowdfunding platform. The researchers collected these brain data and behavioral ratings, and compared them to the actual outcomes on the crowdfunding platform. For the behavioral ratings, ratings of liking, perceived likelihood of success, and positive arousal ratings were significantly associated with individual funding choices, but neither individual funding choices nor participants' self-reported measurements, including project likeability and perceived likelihood of success, predicted the market outcome (i.e. whether the project met its funding threshold on the crowdfunding platform). On the other hand, both NAcc and medial prefrontal cortex (MPFC) activities predicted individual funding choices, but only NAcc activities were found to successfully predict the internet result of crowdfunding outcomes. NAcc was associated with affective evaluation and positive arousal, and was associated with value integration. The findings of brain data were not only consistent with the findings of behavioral ratings that positive arousal was strongly associated with individual choice, but also provided evidence that affective evaluation might generalize from individual choice to aggregate outcome (Genevsky et al., 2017). Similarly, Stallen and colleagues set up a study to investigate whether anticipatory

affective brain activity (i.e. NAcc and AIns) could predict aggregate choice in stock market (2021). They found that NAcc activity, which was associated with positive aroused affect and approach behavior, predicted stock price direction, while AIns activity, which was associated with negative or generally aroused affect and avoidance behavior, predicted stock price inflections (Stallen et al., 2021).

Although previous findings (Genevsky &Knutson, 2015; Genevsky et al., 2017; Stallen et al., 2021) all suggested that only affective processes (i.e. NAcc and AIns) could predict market outcome, Veillette et al. explored the possibility of whether early sensory processing could forecast aggregate choice using EEG (2023). While previous research all used fMRI which had better spatial resolution, Veillette et al. utilized the high temporal precision of EEG to separate very early sensory response from later processing (2023). They replicated the crowdfunding experiment by Genevsky et al. (2017) using EEG, and found that trial-by-trial variations in visually-evoked response obtained in response to image stimuli could forecast both individual choices and market-level outcomes. In addition, their results suggested that while early sensory processing was predictive of individual and aggregate choices, later conscious processes also contribute in predicting market-level outcomes. Moreover, based on the results of early EEG responses, Veillette et al. (2023) used neural forecasting of market-level outcomes and related it to implicit decision-making. Dijksterhuis et al. (2006) argued that people make better complex consumer choices when these choices are made intuitively without reflection, and the EEG results reported by Veillette et al. (2023) are consistent with this. However, this argument has been challenged by several later studies. For example, to test the advantage of the unconscious condition compared to a control condition (i.e. “immediate” condition), and to fix the interfering nature of the materials used in Dijksterhuis et al. (2006), Rey et al. conducted a replication study

(2009). In this study, Rey et al. divided participants into “unconscious”, “conscious”, and “immediate” conditions. The “unconscious” condition used the same design as in Dijksterhuis et al. (2006), asking participants to perform a distraction task for 4 minutes before making the decision. In the “conscious” condition, participants were given the descriptions of the 4 types of cars they would choose among for 4 minutes, instead of memorizing the description, to avoid the interference of materials. Specifically, Rey et al. added an “immediate” condition to act as the control condition, where participants were asked to make their decisions right after being exposed to the descriptions of the cars. Their findings indicated that participants in the “immediate” condition (i.e. 80% chose the best car) performed descriptively better than participants in the “unconscious” condition (i.e. 63.3% chose the best car), and significantly better than participants in the “conscious” condition (i.e. 50% chose the best car), while performances in “unconscious” condition was higher but not significantly better than in “conscious” condition (Rey et al., 2009). Such results indicated that the worse performance in “conscious” condition was due to further conscious processing, that is, spending additional time to contemplate on the decision after the initial impression. Both results reported by Rey et al. (2009) and Veillette et al. (2023) emphasized the importance of preconscious processing in decision-making. While Rey et al. (2009) suggested that additional conscious processing negatively impacted the accuracy of predicting final choice, Veillette et al. (2023) acknowledged the role of later conscious processing in predicting aggregate choices. However, Veillette et al. (2023) pointed out that such predictions were less accurate than the predictions of individual choices based on early sensory processing, which echoes the findings reported by Rey et al. (2009).

Among previous studies, Genevsky and Knutson (2015) and Genevsky et al. (2017) both showed that neural activities during individual decision-making processes can predict aggregate market choice. Additionally, while some of the results found by Veillette et al. (2023) suggested potential involvement of later conscious processes in decision-making process for aggregate choice, their findings primarily indicated that preconscious processes play a significant role in decision-making, consistent with findings reported by Dijksterhuis et al. (2006) and Rey et al. (2009). Although previous findings suggested that both preconscious and conscious processes contribute to decision-making processes from a neural perspective, behavioral evidence would provide further valuable insights into how these processes influence individual and aggregate choice.

The present study is designed to test whether preconscious processes can predict individual and aggregate choice. Genevsky et al. (2017) found that certain behavioral ratings could predict individual choice, but not aggregate choice. Veillette et al. (2023) found that while early sensory processing was predictive of both individual and market-level choices, later conscious processing was likely to play a role in predicting aggregate outcomes as well. Their findings suggest that preconscious processes have high probability of predicting individual choice, but the impact of preconscious processes on forecasting aggregate choice still remains to be explored. Furthermore, such predictability has yet to be demonstrated using purely behavioral methods.

The present study employs the “breaking continuous flash suppression” method to address this research question (Stein et al., 2011). This research technique enables examination of visual processing outside of conscious awareness, corresponding to our research purpose. We intend to measure the time needed for masked artwork to “break through” the interocular

suppression that participants experience, which is the breakthrough time. “Break through” is a term used in the breaking continuous flash suppression (b-CFS) method. In this context, “break through” refers to a moment when the stimulus that is initially visually suppressed becomes visible to the observer (Yang et al., 2014). The stimulus has been present the whole time even though it is not consciously perceived, and is processed at unconscious levels. When the suppressed stimulus “breaks through”, it represents that the unconscious processing has reached the threshold and enters conscious awareness (Carmel et al., 2010). We intend to investigate whether preconscious processing is predictive of individual and aggregate choice, by examining the relationship between breakthrough time and individual preference, as well as its association with auction prices of artworks. Both associations have been supported by Genevsky et al. (2017) and Veillette et al. (2023). The behavioral evidence provided by our study indicates that there are some components affecting the decision-making process before individuals entering into the conscious stage, and thus shows that the critical stage of decision-making happens during the unconscious process.

Current Study

Can a behavioral index of preconscious processing predict individual and aggregate choice outcomes, in order to understand the role of preconscious processes in decision-making? Previous findings such as Genevsky et al., (2017) have shown that neural activity is effective in predicting both individual and aggregate choices. Yet, behavioral evidence supporting the role of preconscious processes in predicting both individual and aggregate choices still remains to be established. Our research aims to address the gap by providing behavioral evidence for the role of preconscious processes in predicting both individual and aggregate decision-making outcomes.

We have framed two research questions for this study. First, is the time needed for masked artwork to "break through" the interocular suppression (breakthrough time) associated with the auction price (i.e. aggregate choice) of the masked NFT artworks? Based on previous research showing that neural activity such as NAcc activity predicts aggregate outcome (Genevsky et al., 2017), we propose that the breakthrough time is not associated with the price of the artworks. The alternative hypothesis is that the breakthrough time is associated with the price of the artworks. The hypothesis builds on the established link between preconscious processing and aggregate choice (Veillette et al., 2023). Second, is the breakthrough time associated with conscious individual preferences for the artworks? Based on previous research showing that neural activity such as NAcc and MPFC activities predict individual outcomes (Genevsky et al., 2017), we propose the following hypothesis for this research question. The null hypothesis is that the breakthrough time is not associated with the individual preferences. The alternative hypothesis is that the breakthrough time is associated with the individual preferences. The hypothesis is justified based on the prior findings that NAcc activity can predict both individual and market level outcomes (Genevsky &Knutson, 2015). The null hypotheses of both questions are unlikely to be supported because previous findings have indicated that decisions in both individual and aggregate levels can be predicted by certain neural activities. For example, Genevsky and colleagues found that NAcc activity could predict both individual and aggregate outcomes (2017). Therefore, we expect an association to appear between the breakthrough time and the auction price. In addition, we also expect an association to appear between breakthrough time and individual preference.

Method

Participant

Participants were students at University of Chicago. We recruited 37 subjects from the SONA system. Each participant was rewarded 1.5 credits for participation. No specific demographic characteristic was required, but the basic demographic data were recorded, including sex, age, and handedness. Participants all reported normal or corrected to normal vision.

37 subjects were run in total. We excluded data of 1 subject because her data indicated that she was responding randomly rather than performing the task as intended. Among the remaining 36 subjects, 26 were female, 33 were right-handed, and average age was 19.56.

Material

Stimulus

Non-Fungible Token (NFT) artworks are used as stimuli in this study. NFT artwork is a digital asset, which is a new form of asset based on blockchain technology (Chen et al., 2022). NFT represents the digital proof of ownership attached to an asset (Chalmers et al., 2022). In this case, it's attached to digital artworks. In this study, NFT artwork is referred to the digital artworks or the images of these artworks. Images of NFT artworks were collected from Larva Labs (Larva Labs, n.d.). We collected artworks that were traded in 2020-2022. 186 artworks were collected in total. All images were monochrome.

Price

Prices of the corresponding artworks were the most recent sale prices collected from Larva Labs as of the last day of 2022, and prices were adjusted for inflation according to the consumer price index (Larva Labs, n.d.). The prices listed by Larva Labs were in ETH at the time of the transaction. Prices were converted from ETH to USD using the conversion rate at the

time of the transaction, and then were adjusted to their value in the most recent year available (as of Dec 13, 2023) using the "CPI-U" index recommended by the Bureau of Labor Statistics. This was done using the “cpi” package in Python.

Breaking continuous flash suppression

Breaking continuous flash suppression (b-CFS) is an experimental paradigm used to investigate visual processing outside of conscious awareness (Stein et al., 2011). When two dissimilar images are presented to two eyes separately at the same location, one image dominates the awareness, while the other is suppressed. If stimuli presented to opposite eyes are of similar strength, dominance alternates periodically, typically every few seconds. This is binocular rivalry (Carmel et al., 2010). Continuous flash suppression (CFS) is a variation of binocular rivalry in which one stimulus is presented more strongly (i.e. higher contrast/intensity, regularly flashing) than the other to ensure suppression of the stimulus in the other eye. It is frequently used to investigate the processing of the suppressed image because the target stimuli can be completely suppressed for a few minutes, much longer than ordinary binocular rivalry (Carmel et al., 2010). In this study, CFS is produced by presenting rapidly flashing masks to one eye, while presenting a to-be-reported target stimulus to the other eye. At some timing relationships the target stimulus is invisible to the participants due to the mask in the other eye. The researchers measure the time taken for the participants to see the target (i.e., to “break through”) even when the masking is present as suppression. Participants were instructed to indicate which side the masked target is on as fast as possible by pressing the left or right button on the keyboard. The response time taken for participants to report seeing a target image is the breakthrough time, which may reflect the unconscious processing during suppression (Yang et al., 2014). We used a pair of 3-D glasses with one red lens and one blue lens so that different images can be presented to the different

eyes, because the red lens only transmits red light, while the blue lens only transmits blue light. In this experiment, the masks are flashing high-contrast images, operationalized as circles varying in their red pixel values flashing at 10 Hz. Masks were presented on the computer screen in the lab. They were 740 x 740 pixels on a 1920 x 1080 pixels display, which was 22 x 11 inches. The distance between the screen and the seat was approximately 2 feet. The target stimuli were auctioned NFT artworks that were filtered in blue, and was 247 x 247 pixels. In this case, the participants only saw the flashing masks through the red lens, and the stimuli through the blue lens, creating CFS. The flashing mask in the background was at 100% contrast, while the stimuli increased from 0% contrast to 50% contrast over 2 seconds, then remained at 50% contrast. As the contrast of the target stimuli gradually increases from 0% contrast to 50%, they become more visible to the one eye that can see them, while remaining suppressed from the continuous flashing masks seen by the other eye.

Procedure

Subjects were tested in the lab with computers and anaglyph glasses (similar to those used in viewing a 3-D movie) that allow only red light through one lens and blue through the other, allowing separate visual stimuli to be presented in each eye (Carmel et al., 2010). At the beginning of each testing session, participants gave verbal consent after reading the consent form, and filled out a demographic information questionnaire. Before the experiment started, participants were asked to sit in front of the computer, wear a pair of anaglyph glasses, and follow the instructions on the screen. The experimenter turned off the light before the experiment started.

Block 1: breaking continuous flash suppression

Subjects were tested in 3 blocks of trials. In the first block, participants saw many circles in different sizes varying in their red pixel values flashing at 10 Hz at 100% contrast in the background in the eye behind the red lens (mask stimulus), with blue stimuli (target stimulus, i.e. the NFT art) gradually increase its contrast from 0% to 50% over 2 seconds seen in the other eye behind the blue lens. The stimulus could appear on either one of the following four locations on the mask: upper left, upper right, lower left, and lower right. Participants were instructed to press a button, either left or right, once they see the target artwork stimulus. Using the b-CFS method, the induced interocular suppression would mask the artwork from conscious awareness at the beginning of the trial (Carmel et al., 2010), but eventually, the masked artwork would "break through" the interocular suppression, at which point the participants would indicate that they see the stimulus with a button press. Their response time was recorded as the breakthrough time for each target. There were 186 distinctive stimuli in total. One stimulus was displayed per trial, and every stimulus was displayed only once in this block. Each participant was tested on 186 trials.

Block 2: control

In block 2, participants saw many black and white circles flashing at 10 Hz at full contrast in the background, with black and white stimuli gradually increase contrast from 0% to 50% over 2 seconds. The stimuli could appear in one of the four corners of the masked locations as in the b-CFS condition. As white light can pass through both the red and blue lenses of the anaglyph glasses, both stimuli were presented to both eyes in this condition and no interocular suppression occurred (Stein et al., 2011). The control condition maintained the same processes as in the b-CFS condition except for the ones that rendered strong interocular suppression (Yang et al., 2014). Thus, this condition allowed us to measure, and thus control for, stimulus-specific differences in response time that were unrelated to interocular suppression. Participants received

the same instructions as in the previous block. Each participant was tested on 186 trials without repetitive presentation of the artworks.

Block 3: individual preference

In block 3, two black and white artworks appear simultaneously on the screen side by side. The artworks were 160 x 160 pixels each at 100% contrast. Participants were asked to take off the 3-D glasses, and choose their preferred image between the two shown on the screen. Images were presented for at least 4 seconds for each trial to encourage participants to choose consciously. Each participant in this block was tested on 200 trials. 200 distinctive pairs of artworks were randomly selected from all possible combinations of artworks. We decided to select 200 pairs out of 17205 (=n*(n-1)/2=186*185/2) possible combinations. It was impossible for participants to go through all the possible combinations. Considering 186 trials were run for each of the previous two blocks, and we wanted to finish the experiment in 1.5 hours, we chose 200 as a fair number of trials for this block.

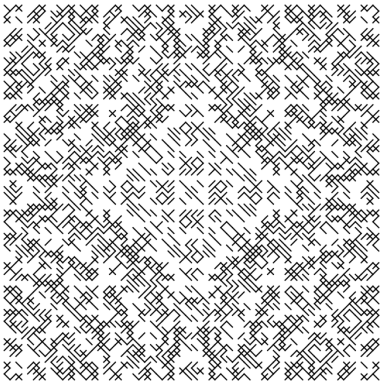

Figure 1: Sample stimulus

Figure 2: Sample mask image

Results

Analysis

Breakthrough time v. auction price

We used three methods to estimate the relationship between breakthrough time and auction price in the CFS condition. First, we used Pearson's Product-Moment Correlation Coefficient to examine whether there is a linear relationship between breakthrough time and auction price. In this analysis, we took the average of breakthrough time over 36 subjects in the CFS condition for each of the 186 pieces of artwork. We then correlated the price of each piece of artwork with the average breakthrough time for that piece of artwork. This analysis revealed a non-significant linear relationship between the average breakthrough time per subject and the auction price of each piece of artwork, $r = 0.05$, $t\ (df=184) = 0.70$, $p = 0.49$, with a 95% Confidence Interval of [-0.09, 0.19]. Second, we used Spearman's Rank Order Correlation Coefficient to investigate whether there is a non-linear relationship between breakthrough time and auction price. We found a non-significant non-linear relationship between the average breakthrough time per subject and the auction price of each piece of artwork, $\rho = -0.06$, $p = 0.42$. Finally, we calculated the Pearson correlations between price and breakthrough time for each subject, and took a One-Sample t-Test of these correlations to examine whether there is significant correlation between price and breakthrough time. The results indicated that there is no significant linear relationship between breakthrough time and price of artwork in CFS condition when analyzed at the subject level, $t\ (df=35) = -0.02$, $p = 0.99$, with a 95% Confidence Interval of [-0.03, 0.03].

In addition, we used the same methods to investigate the relationship between breakthrough time and auction price in the control condition. The Pearson correlation between the average reaction time and artwork price is $r = 0.07$, $t\ (df=184)=0.89$, $p=0.37$, 95% CI [-0.08, 0.21]. The Spearman correlation is $\rho=0.10$, $p=0.16$. The One-Sample t-Test comparing the mean of 36 correlation coefficients to zero yielded $t\ (df=35) = -0.70$, $p=0.49$, 95% CI [-0.03, 0.02]. The

results of all three analyses suggest that there is no significant correlation between breakthrough time and auction price in the control condition.

In addition, a Paired t-Test on Fisher Z-Transformed Correlations was used to compare the correlations between breakthrough time and auction price in the CFS condition and Control condition on a subject level. The results indicate that there is no significant difference between the correlations in the CFS and control conditions, t (df=35)=0.44, p=0.66, 95% CI [-0.03, 0.04].

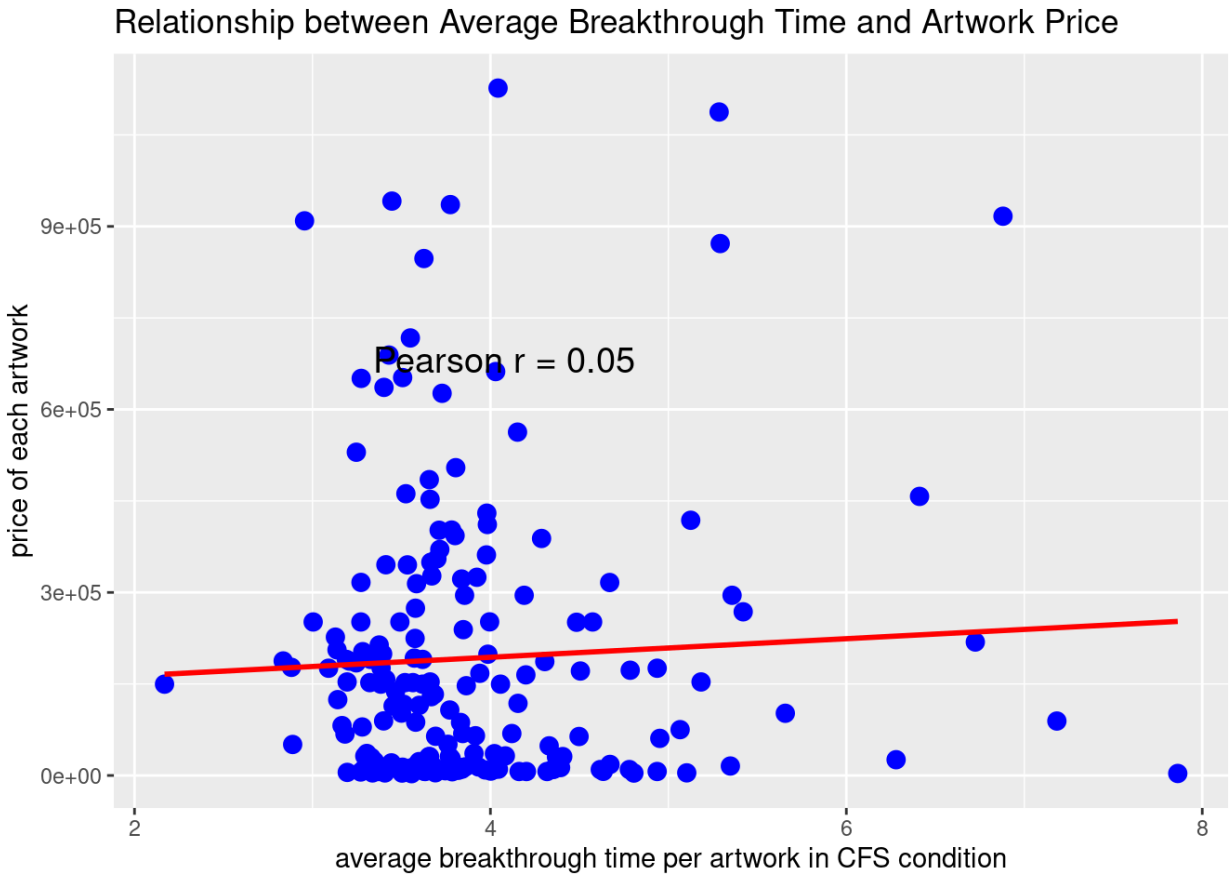

Figure 3: Scatter plot of Pearson correlation between average breakthrough time per artwork in CFS condition and price of each artwork

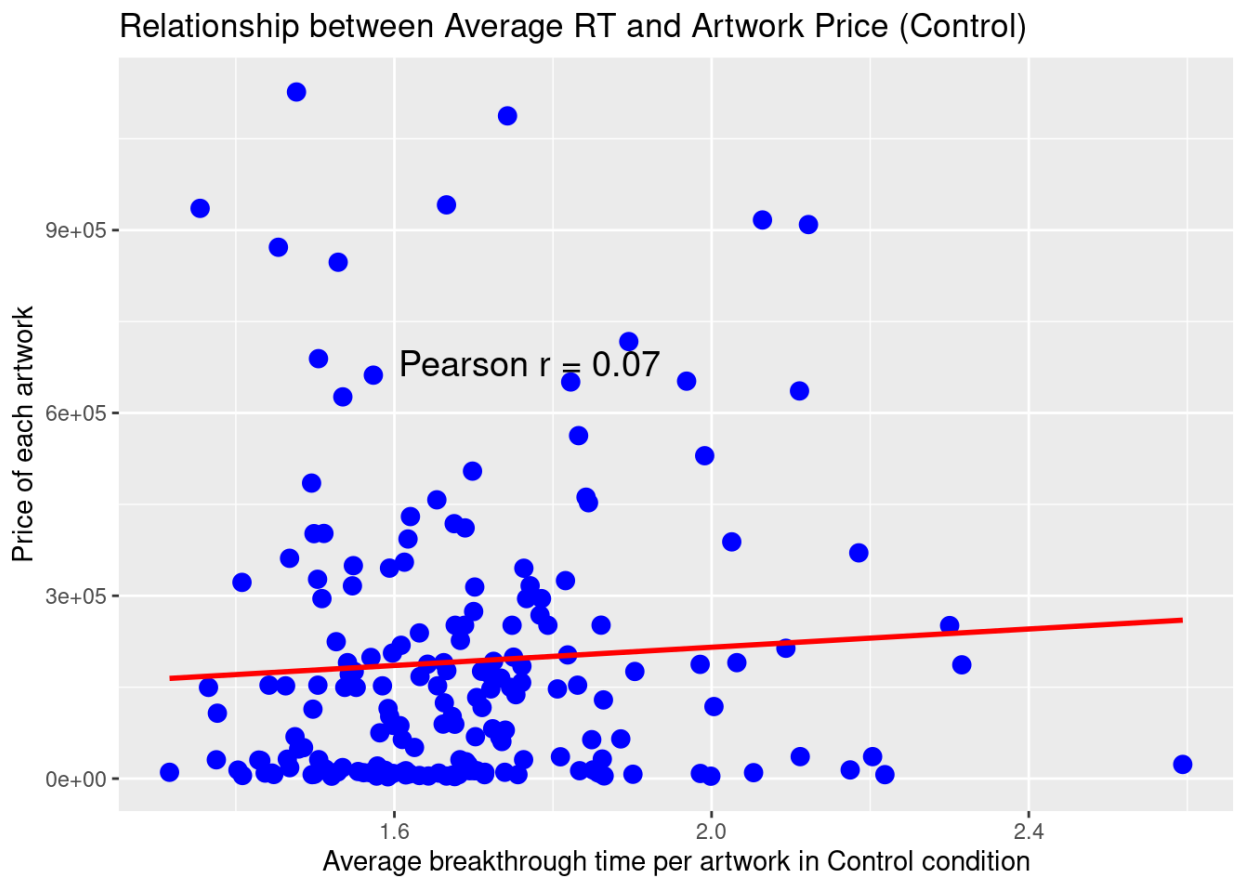

Figure 4: Scatter plot of Pearson correlation between average breakthrough time per artwork in Control condition and price of each artwork

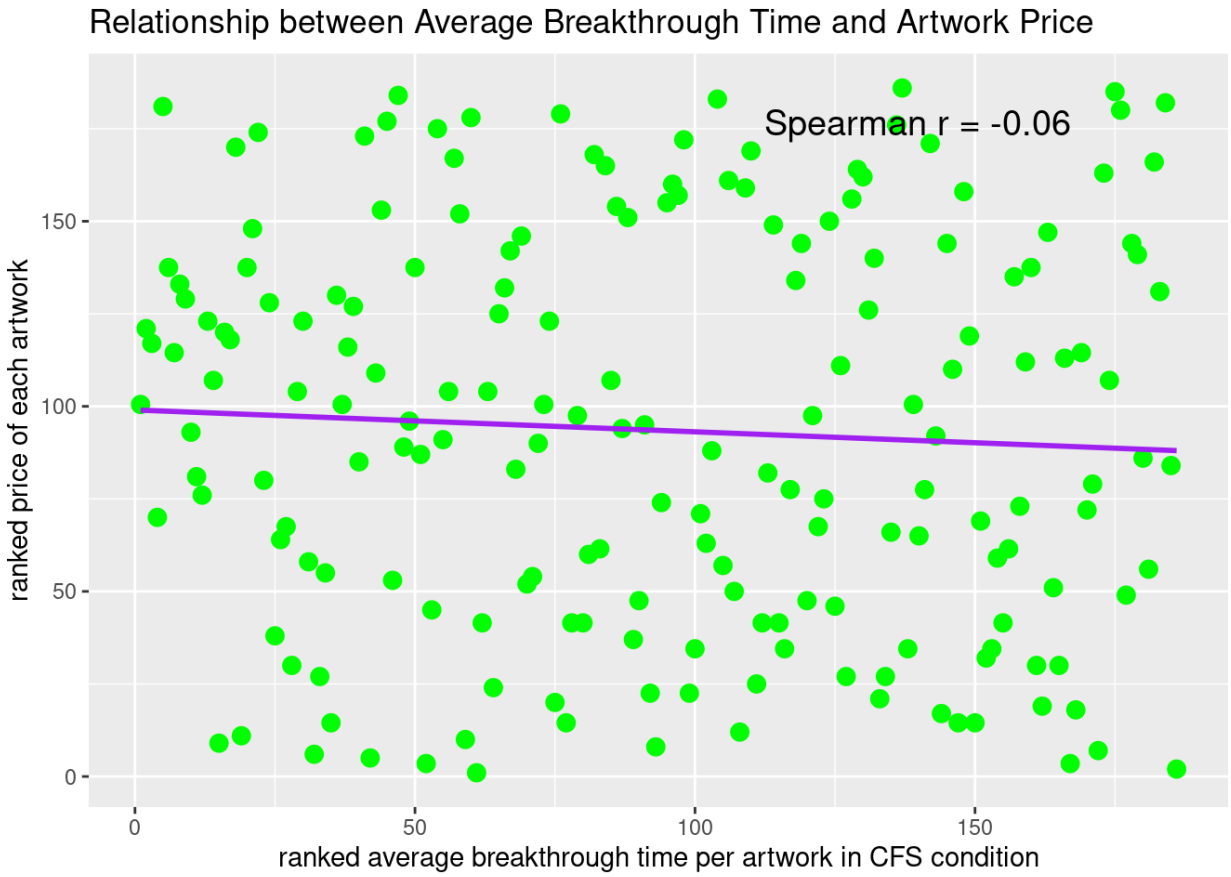

Figure 5: Scatter plot of Spearman correlation between ranked average breakthrough time per artwork in CFS condition and ranked price of each artwork

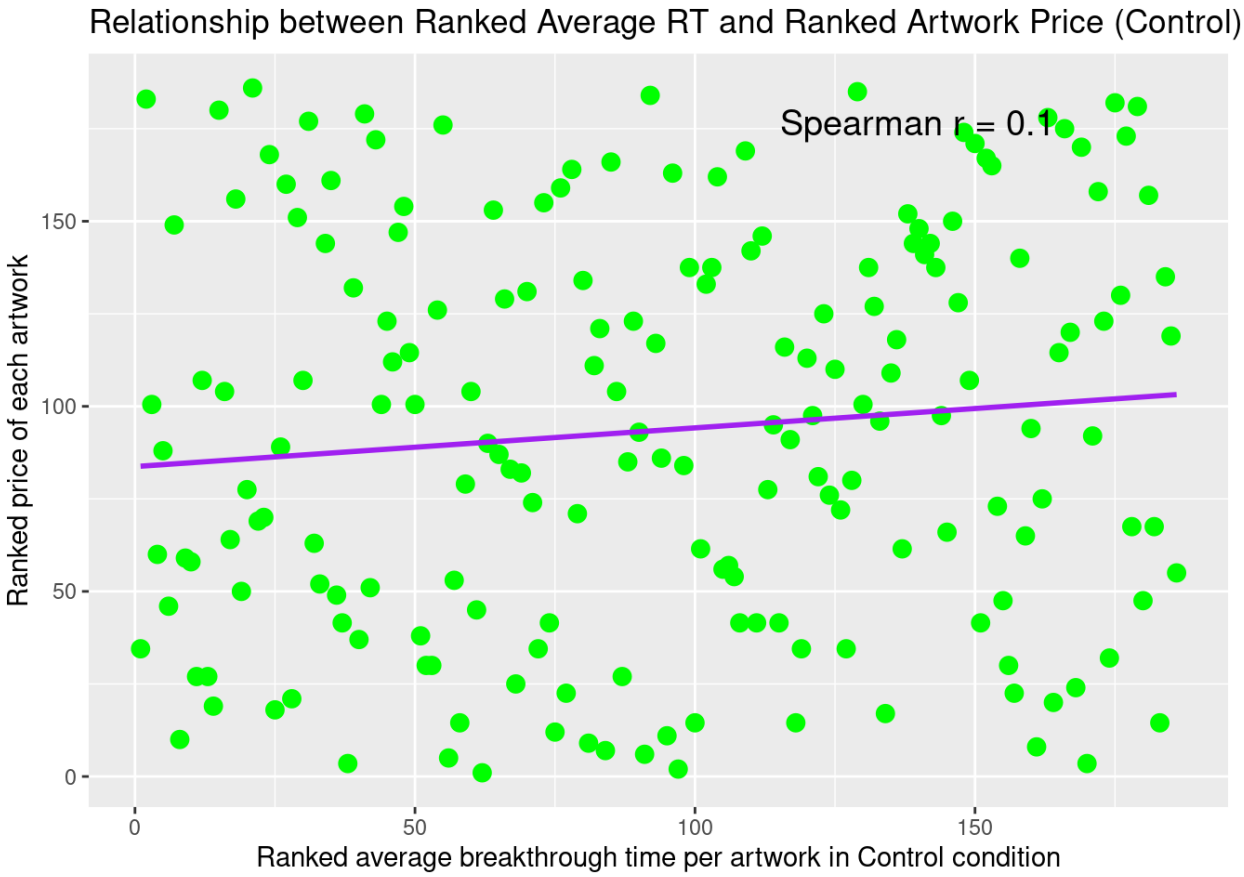

Figure 6: Scatter plot of Spearman correlation between ranked average breakthrough time per artwork in Control condition and ranked price of each artwork

Figure 7: Histogram of subject-level Pearson correlation coefficients between artwork price and breakthrough time in CFS condition

Figure 8: Histogram of subject-level Pearson correlation coefficients between artwork price and breakthrough time in Control condition

Breakthrough time v. conscious individual preference

We predicted that between the 2 compared artworks in block 3, the artwork with shorter breakthrough time would be preferred. We compared the CFS breakthrough time of the two pieces of artworks presented in each trial in block 3. If the stimulus with shorter breakthrough time is preferred by the subject, the trial is scored 1, otherwise, it's scored 0. We calculated the mean of the scores across all trials, and a One-Sample t-Test of the result was compared against 0.5, which corresponds to the score at chance level. The results of the analysis showed that the average score is approximately equal to 0.5, and indicated that there is no significant bias in

preferring artwork with shorter breakthrough time, average score = 0.499, t (df=7199)= -0.09, p=0.92, 95% CI [0.49, 0.51].

Discussion

In the present study there is no significant relationship between the breakthrough time and the auction price of the artwork, or between the breakthrough time and individual preference. Unfortunately, this does not allow us to draw any conclusions about the type of reasoning or assessment related to choice processing in this study.

Breakthrough time v. auction price

Our results show that there is no significant association between the breakthrough time and auction price. In the scatter plot of Pearson Correlation of between average breakthrough time per artwork in CFS condition and price of each artwork (Figure 3), most data points cluster in the lower left region, with a few dots spreading in other locations. The lower left cluster indicates that there is little association between price and average breakthrough time. However, despite limited statistical support, we observed that there are more data points in the upper left region than in the upper right or lower right region, suggesting that there might be a trend of higher priced artworks take less time to enter awareness. Moreover, in the scatter plot of Spearman correlation between ranked average breakthrough time per artwork in CFS condition and ranked price of each artwork (Figure 5), the data points are displayed uniformly across the plot, showing no discernable trend between the two variables. In addition, the histogram of subject-level Pearson correlation coefficients between artwork price and breakthrough time in Figure 7 visually shows that correlations are narrowly distributed around zero, suggesting that there is little linear association between price and breakthrough time for most subjects. Overall,

these plots are all consistent with the statistical results, reinforcing the conclusion that there is no relationship between breakthrough time and auction price in the CFS condition.

Neural method v. behavioral method

Previous studies have suggested that neural activity can be predictive of market choices (Genevsky & Knutson, 2015; Genevsky et al., 2017; Stallen et al., 2021; Veillette et al. 2023). Specifically, Genevsky and Knutson found that some neural activity was more predictive of the success of the ultimate microloan request than conscious individual choice, suggesting that there should be some association between preconscious processing and the aggregate choice. However, it's also important to note that most evidence of the prediction is based on neural data, instead of behavioral data. Although we were trying to provide the behavioral evidence for this association between preconscious processing and aggregate choice, our approach didn't yield a promising result. It appears the neural responses are more sensitive to the difference in processing.

Validity of method

Unfortunately, several parts of the design might undermine the sensitivity of the present method. First, the preconscious processing is operationalized as the time taken for participants to consciously see the stimuli on the screen. According to Carmel et al. (2010), although the CFS breakthrough time can potentially reflect preconscious processing, there are other possibilities and concerns that put doubts on interpreting the breakthrough time as direct evidence of preconscious processing. Besides interpreting the breakthrough time as preconscious processing, Carmel et al. also suggested that b-CFS could be understood as a sensitive measure of detection threshold differences between stimuli (2010). In this case, shorter breakthrough time indicates lower detection threshold instead of unconscious processing. In addition, Carmel et al. also

pointed out that breakthrough time might reflect general detection advantages that do not exist in CFS specifically (2010). This issue might be improved by comparing the results of the CFS condition and the control condition. The result of the comparison is not significant. However, Carmel et al. even doubted that this comparison might not be truly comparable (2010). Therefore, the measurement of breakthrough time might not accurately represent preconscious processing.

Moreover, market choice is operationalized as the auction price of each NFT artwork. However, there are several factors that might cause the auction price to not accurately represent market choice. First, NFT artwork is a newly developed concept that is rapidly evolving in the digital art world, and has likely attracted only certain tech-savvy and art-collecting circles, but has yet to raise attention in the mainstream population. In addition, the nature of auction as an activity has selected its own audience whose demographic characteristics might differ drastically from the general population. The potential mismatch between the demographic characteristics of the participants and those of the typical NFT artwork audience could potentially cause discrepancy in the assessment of aesthetic preferences and perceived market value. This discrepancy may lead to the disparity between the aesthetic judgements observed in our study and the bidding price resulted in real-world auctions. Consequently, the association between the breakthrough time based on aesthetic judgements observed in our experiment and the actual price collected from real-world auction may be weak or even non-existent. This potential disconnect exhibits the limitations of mismatching demographic characteristics and generalization ability.

Breakthrough time v. individual preference

Our results fail to show that the subjects choose the artworks with shorter breakthrough time over chance level. Unfortunately, although the program forced the participants to stick with each trial for at least 4 seconds to ensure their choices were consciously processed, the participants had generally lost their patience during block 3, due to the long and repetitive process of this experiment. Thus, it is possible that they were making more random choices that would reflect preferences.

General discussion

The present results fail to inform about either preconscious processing or conscious decision-making. Using a behavioral approach, our findings cannot address previous findings using neural measures. There is uncertainty in almost every step of the design of the study. For example, choosing participants from the corresponding demographic to ensure comparability between data, standardizing experimental conditions for all participants for each block to reduce potential confounding factors, and evaluating the operationalized measures to ensure accurate assessment and construct validity.

Exploring the association between preconscious processing and aggregate choice has potential value in real-world applications. If a robust and replicable method can establish a significant association between preconscious processing and aggregate choice, with the former being predictive of the latter, it could revolutionize market research by predicting the market outcome using a relatively small sample size. This has significant economic implications for retail corporations, especially in the strategic decision-making process for specific products. For example, it could reform the approach of assessing consumer preference for a new automobile model prior to establishing production lines. By enabling effective forecasts of general consumer preferences through testing with small sample sizes, this approach could potentially yield

significant cost savings in the early stages of product development. Furthermore, the demand for accurate forecasting extends to the realm of electoral politics, such as presidential elections. For instance, a candidate's attire could be evaluated prior to public appearances to select the most favorably perceived outfit. By applying this approach, the campaign team could potentially implement regional customization of the outfit, strategically tailoring the visual appearances to align with local preferences, thereby optimizing the electoral outcomes. In short, the predictive relationship between preconscious processing and aggregate choice has numerous potential applications with substantial economic value across various fields.

Future research that continues exploring the association between preconscious processing and aggregate choice should be cautious with the methodological approach. The researchers need to pay particular attention to match the demographic of the subjects who participate in the experiment, and the demographic of the population from whom they collect data for comparison. In addition, researchers may conduct experiments using both behavioral and neural methods with the same subjects and the same content. Applying both approaches at the same time allows researchers to compare the results of each approach, and thereby examine whether the association between preconscious processing and aggregate choice exists under certain conditions, and which approach is more effective in yielding significant results.

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