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Assigning Economic Value to People Results in Dehumanization Brain Response

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For a profit-maximizing rational agent, labor markets present a paradox: Economic contexts encourage exploitation of commodities whereas social contexts discourage exploitation of people and instead promote empathic responding and moral protection. This may result in irrational behavior. Perhaps rational agents reduce spontaneous social–cognitive responses to successfully maximize profits in a labor market. We tested this hypothesis by creating a labor market—an economic market where people serve as commodities. fMRI participants initially purchased players from a time-estimation skill labor market, then revalued these players based on performance in an attempt to maximize profit. Despite implementing a variety of purchasing strategies, we find that participants initially reduce activity in social cognition brain regions when viewing purchased players—an initial reduction consistent with a dehumanized brain response—that predicts later revaluation of purchased labor market players. However, traditional valuation regions in medial orbito-frontal cortex (MOFC) predict nonpurchased players' revaluation. These results suggest valuation and social cognition brain regions independently guide revaluation processes when people are treated like commodities.

Keywords: dehumanization, subjective value, social cognition, economic value

Human beings establish economic markets to facilitate the creation and consumption of goods and services (commodities). The price of said commodities is determined by the rules of supply and demand, giving rational agents in the market the power to assign price to commodities in an attempt to exploit these economic forces (Arrow & Debreu, 1954). Imperative to being an effective agent in the market is the ability to accurately assign price or to subjectively value a commodity. Doing so ensures that a buyer does not overpay for a commodity and a seller gets full value for the commodity. Recent neuroscience research delineates neural processes underlying the valuation of goods in economic markets, identifying medial prefrontal cortex (MPFC; Levy, Lazzaro, Rutledge, & Glimcher, 2011), medial orbito-frontal cortex (MOFC; Litt, Plassmann, Shiv, & Rangel, 2011; Plassmann, O'Doherty, & Rangel, 2007), and striatal regions, including ventral striatum (Gregorios-Pippas, Tobler, & Schultz, 2009; Kable & Glimcher, 2007; Knutson, Taylor, Kaufman, Peterson, & Glover, 2005) and caudate (Sakagami, 2013), along with specific neurotransmitters such as dopamine (Schultz, Dayan, & Montague, 1997) and serotonin (Zhong et al., 2009; Long, Kuhn, & Platt, 2009). These neural mechanisms integrate subjective value and prediction error signals to guide behavior.

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But what happens when human beings themselves are the commodities in economic markets, as occurs in labor markets? Research shows person perception results in spontaneous social cognition, implicating a network of brain regions including MPFC, temporal-parietal junction (TPJ), parts of temporal lobe including superior temporal sulcus (STS) and anterior temporal pole (ATP), and precuneus (Amodio & Frith, 2006; Frith & Frith, 2001; Gallagher & Frith, 2003; Haxby, Gobbini, & Montgomery, 2004; Van Overwalle, 2009), along with hormones such as oxytocin (Kirsch et al., 2005; Ross & Young, 2009) and vasopressin (Donaldson & Young, 2008; Heinrichs, von Dawans, & Domes, 2009) in this process. Spontaneous social cognition processes facilitate social interaction, but may hamper effective subjective valuation processes necessary for profit maximizing rational agents. Although submitting people as commodities to economic forces may encourage exploitation for profit, moral rules reserved for social interaction among humans discourage such exploitation. Perhaps spontaneous engagement of social cognition hinders economic valuation processes for people, invoking moral rules that do not traditionally apply to commodities in economic contexts. We hypothesize that spontaneous social cognition must first be regulated before price or subjective value can be assigned to people in order to maximize profits.

Previous social neuroscience research has demonstrated that it is possible to withhold spontaneous social cognition to people, documenting reduced activity in the social cognition brain network across a variety of participants and among varied human populations as targets. This dehumanized brain response occurs in healthy adults when viewing members of extreme social outgroups (see Harris & Fiske, 2009 for review), in males viewing scantily clad females (Cikara, Eberhardt, & Fiske, 2011), and in experienced video game players before pulling a trigger to eliminate an enemy in a violent first person shooter game (Mathiak & Weber, 2006). This reliable reduction of the social cognition brain network across a variety of social contexts demonstrates a boundary condition to this cognitive ability. Moreover, it suggests that this reduction of the social cognition brain network may serve an evolutionarily preserved function. Specifically, having the ability to attenuate social–cognitive processing may facilitate behavior otherwise reserved for nonhuman agents, such as harming others, or perhaps even exploitation that can occur in economic markets. This suggests that any person could reduce social cognition, and any group of people could engage this dehumanized perception (Harris & Fiske, 2006, 2011) if the social context rewards behaviors otherwise reserved for nonhuman agents.

Here, we combine the neuroeconomic and social neuroscience literatures to test the hypothesis that activity in the social cognition brain network reduces to facilitate engagement of valuation when people serve as commodities. We created a "labor market" using a sample of players who participated in a competitive time estimation game. This game required players to accurately estimate intervals of time (e.g., 9.5 s) by pressing a button to start and stop a timer when they believed the interval had elapsed. Accuracy was determined within a 500 ms window above and below the target time, resulting in a normally distributed sample (skew $= -.364$; kurtosis $= .855$) of the accuracy of time estimation players. We assigned a value (price) to each of these players based on their accuracy such that more accurate players were more expensive. Labor supply in this market was fixed to the 60 players (Sample 1 participants) who completed the task. We then endowed a second sample of participants with $25, allowing them to purchase five of the 60 players from this time estimation labor market for a chance to earn a profit based on purchased players' performance. At least one week later, the "owners" of the purchased players (Sample 2 participants) observed sequentially while in the scanner: (a) pictures of purchased and nonpurchased players from the labor market, (b) the target time players had to estimate, and (c) the outcome of a player's actual performance on the time estimation task (chosen at random from player's previously recorded behavior), before having the opportunity to (d) revalue each player (see Figure 1). Importantly, the scanner participants' outcomes (money won in the experiment) were dependent on purchased players' performance from randomly selected trials presented during scanning chosen at the end of the experiment. Ideally, we could measure initial purchasing activity in the brain. But here we are interested in psychological and brain processes associated with assigning value to people already pur-

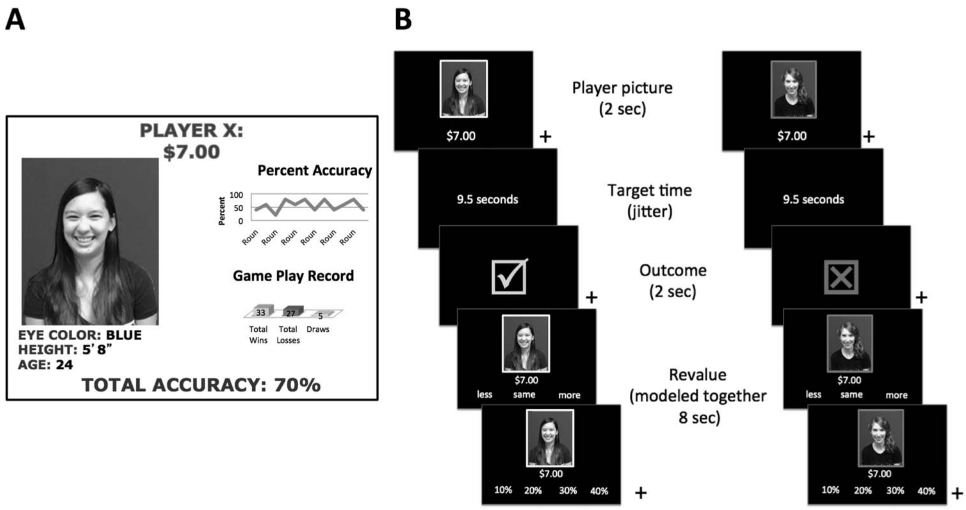

Figure 1. *Study design.* (A) Prior to the fMRI session, participants viewed profiles of the 60 players in the labor market before purchasing five players. Profiles included the player's picture, information about their time estimation behavior, and a price based on their accuracy. (B) In Session 2 (fMRI task) each trial began with a picture of the player, outlined in yellow or pink to indicate that the player was purchased/not purchased, and the assigned price. A target time was displayed for a jittered duration (2–8 s). The participant viewed the outcome of the player's time estimation (correct indicated by green check; incorrect indicated by red X) before revaluing the player. The participant had 4 s to indicate if the price should be less, the same, or more than the original price and 4 s to indicate, if different, by what percentage the player's price should be increased or decreased, ranging from 10%–40%. For trials in which participants indicated the price should be the same, they pressed a button at random during the second revaluation screen to control for motor responses. The two revaluation screens were modeled together.

chased, a valuation phenomenon present in economic markets such as sport leagues, rather than simply purchasing behavior. As a result, we fixed initial prices to accuracy, and gave participants the opportunity to revalue or assign value based on performance.

Method

Time Estimation Database: Phase 1

Sixty volunteers (32 female) participated in the first phase of the study ($M_{\text{age}} = 25.28$ years old, $SD = 7.19$). Thirty participants self-reported as Caucasian, 13 as Asian, 12 as African American, and five as other race or ethnicity. Participants played a time estimation game against each other in pairs. The game consisted of guessing when a certain number of seconds (e.g., 9.5) had elapsed. The game was presented using E-Prime software. Participants played 12 rounds total, and in each round both participants had to estimate time on five separate trials. Participants were randomly assigned the role of Player A or Player B. Each round started with a screen that indicated which player's turn it was and the target time they had to estimate, followed by the start screen. Participants pressed the space bar on the computer when they were ready to start estimating time, and pressed it again to indicate when they believed the correct amount of time had elapsed. Each time window was displayed for a maximum of 12 s total, with the time intervals they had to estimate always falling within a 5- to 11-s time frame. After the 12 s had passed, participants saw feedback that indicated whether they were correct or incorrect (correct responses fell within +/− 500 ms of the target time), along with their accuracy (in percentage) for the round and the actual time that they had estimated. Participants received a base rate of $10.00 for participating, and were told that for each round won they would receive an additional $1.00. In the chance of a tie, each participant would receive an additional $0.50.

Individual player profiles were created for each of the 60 participants, containing information specific to the individual and their performance in the time estimation game. Profiles included: the player identification number (e.g., Player 1), a picture of the player's face, physical information (eye color, height, and age), a line graph of percent accuracy over each round of the time estimation game, a bar graph representing total wins/losses/ties, total percent accuracy, and the value or price assigned to the player (e.g., $5.70). A standard template was used for each profile, changing only the information specific to each player. Values were assigned to players based on total percent accuracy, with 0% accuracy resulting in a value of $0 and 100% accuracy resulting in a value of $10. Player prices ranged from $2.00 to $9.50 ($M_{\text{price}}$ = $6.20, SD = 1.396). Participants in the second sample were able to examine all 60 profiles and were given $25 to purchase five players, which precluded them from simply buying the five players with the highest accuracy (the most expensive players).

Brain Imaging Method: Phase 2

Participants

We recruited a second sample of right-handed individuals to participate in the fMRI portion of this study through Duke University's Brain Imaging Analysis Center (BIAC) subject pool. We collected data from 34 individuals (14 female; age: M = 26 years old, SD = 9.62). Of those 34 individuals, seven were removed due to subject or scanner problems, primarily excessive movement or a failure of data recording, resulting in 27 participants. All participants gave informed consent. Brain imaging participants received $22 for their participation, plus any additional winnings (up to $50).

Procedure

Participants came to the lab at least a week before completing the fMRI scan (days between sessions: M = 13.35 days, SD = 19.33). At the beginning of this first session, participants learned about the time estimation game completed by the database players and viewed profiles summarizing these players' behavior in Phase 1. If participants recognized any of the players, that player was excluded from the market during selection. We endowed participants with $25 and gave them an unlimited amount of time to look through all 60 player profiles in the market before purchasing five players. Participants were not required to spend the entire $25 amount (they were allowed to keep any leftover money), but were required to purchase a total of five players. At this time, we also informed them about the opportunity to earn bonus money based on their purchased players' performance, which they would observe during scanning. Specifically, 10 randomly selected trials (two trials for each of their five purchased players) would be selected at the end of the study. For each correct player performance, the fMRI participant would receive $5 in bonus money (a max of $50 bonus money). After purchasing their five players, participants were thanked and received $5 for their participation and any money not spent on purchasing players. Prior to returning for the scan, five nonpurchased players were randomly selected from the remaining 55 players using a random number generator.

During each run in the scanner, participants viewed the time estimation outcomes for their five purchased and the five randomly selected nonpurchased players (total of 10 trials/run). Each trial consisted of a picture of the player displayed for 2 s, the target time the player was asked to estimate (e.g., 9.5 s; jittered duration 2–8 s), the outcome (correct/incorrect) of their time estimation displayed for 2 s, then two revaluation screens displayed for 4 s each and modeled together, where participants indicated (a) whether the player's price should be less, the same, or more than the price assigned at the beginning of the study; and (b) if different, by what percentage the player's price should be increased or decreased, ranging from 10%–40%. For trials in which participants indicated the price should be the same, a random button was pressed during the second revaluation screen to control for motor responses but ignored during analysis. We separated each screen by a jittered fixation ranging between 2–8 s (Ollinger, Corbetta, & Shulman, 2001; Ollinger, Shulman, & Corbetta, 2001) except for the two revaluation screens that were modeled together. Importantly, the outcomes presented to participants in the scanner were the actual outcomes of the players' time estimation behavior from a randomly selected trial in Phase 1. Therefore, if a player was 90% accurate in the time estimation game, there was a 90% chance that the outcome of a trial in the scanner would be correct. After completing 12 runs, 10 trials (two trials for each of the five purchased players) were randomly selected and participants earned $5 for each correct purchased player's performance.

Behavioral Analysis Strategy

We calculated how often participants revalued purchased and nonpurchased players after correct and incorrect outcomes. These percentages were entered into a 2 (Player: purchased/nonpurchased) $\times$ 2 (Outcome: correct/incorrect) $\times$ 2 (Revalue: same/different) repeated measures ANOVA.

To create a revaluation index, we scored each valuation response on a scale from -4 to 4, where -4 indicates the participant felt the players value should be 40% less than the player's original price, 0 indicates the player's price should be the same, and 4 indicates the price should be 40% more than the player's original price. The average of these scores for each participant was taken as a revaluation index and used in the regression analysis.

fMRI Acquisition and Data Analysis

A 3.0 Tesla GE Signa Excite head-dedicated scanner was used to collect structural images (T1-weighted MPRAGE: 256 $\times$ 256 matrix; FOV = 256 mm; 116 1-mm sagittal slices) followed by functional images (EPI sequence: TR = 2,000 ms; TE = 25 ms; FOV = 192 cm; flip angle = 75°; echo spacing = 0.29 ms; 39 slices; voxel size: 3 $\times$ 3 $\times$ 3 mm^3). A computer presented the stimuli projected to a screen mounted at the rear of the scanner bore. Stimuli were reflected through a filter and a mirror, which participants viewed while supine.

BOLD Data Preprocessing

Both image preprocessing and statistical analysis used Brain Voyager QX (http://www.brainvoyager.de). Before statistical analysis, image preprocessing consisted of: (a) slice acquisition order correction, (b) three dimensional (3D) rigid-body motion correction, (c) voxel-wise linear detrending across time, and (d) temporal bandpass filtering to remove low and high frequency (scanner and physiology related) noise. Distortions of EPI images were corrected with a simple affine transformation. Functional images were registered to the structural images and interpolated to cubic voxels. After coregistering participants' structural images to a standard image using a 12-parameter spatial transformation, their functional data were similarly transformed, along with a standard moderate degree of spatial smoothing (Gaussian 8 mm FWHM).

BOLD Data Analysis Strategy

Data analysis used the general linear model available on the Brain Voyager QX software package. We conducted a random-effects GLM analysis on BOLD signal with separate stick-function predictors during the players' picture (purchased/nonpurchased), the outcome (correct/incorrect), and revaluation (less/same/more). We also added predictors for motion correction to the model. We convolved the predictors with a standard canonical hemodynamic response function. We transformed structural and functional data of each participant to standard Talairach stereotaxic space (Talairach & Tournoux, 1988).

Dehumanization Index Creation

We created a dehumanization index (reported in the Results section) to predict brain activity during revaluation. To create this index, we performed a whole brain contrast (purchased > nonpurchased) during the first screen of each trial when participants were viewing the player picture. To correct for multiple comparisons, we used a false discovery rate correction, $q = 0.001$ $c(V) = \ln(V) + e$, resulting in eight clusters (see Table 1). We extracted beta values from each cluster and averaged to create a separate overall signal for purchased and nonpurchased players. We created a difference score from these overall signals to create a dehumanization index. That is, the extent to which a participant reduced activity in these brain regions when viewing a purchased compared with a nonpurchased player.

Table 1
Brain Regions Less Active While Viewing Purchased Compared With Nonpurchased Players' Picture (Screen 1)

Region	BA	Talairach coordinates (*x, y, z*)	Voxels	*t* value	*p* value	Effect size
Superior temporal gyrus	22	62, −41, 14	386	−6.66	4.56E-07	0.63
Middle frontal gyrus	9	50, 7, 37	1765	−7.33	8.82E-08	0.67
Postcentral gyrus	7	−21, −47, 66	28505	−9.39	7.68E-10	0.77
Caudate		−18, −35, 20	16065	−10.91	3.34E-11	0.82
Medial prefrontal cortex	8	−1, 31, 49	2106	−7.76	3.13E-08	0.70
Cingulate gyrus	32	−1, 25, 25	607	−6.93	2.32E-07	0.65
Inferior frontal gyrus	9	−57, 10, 31	777	−6.88	2.64E-07	0.65
Superior temporal gyrus	22	−66, −44, 14	4586	−8.91	2.24E-09	0.75

Note. Data were corrected for multiple comparisons using a false discovery rate of $q = .001$, $c(v) = ln(v) + e$. Talairach coordinates represent peak voxel activation.

Regions of Interest Analyses (ROIs)

Regions of interest (ROIs) were taken from the literature based on a priori hypotheses. In particular, the studies that provide these ROIs are the only ones in the literature with a similar paradigm to the one we employ. Specifically we were interested in regions of MOFC implicated in valuation ($x, y, z = 5, 23, -12$; Lin, Adolphs, & Rangel, 2012) and willingness to pay ($x, y, z = 6, 30, -17$; Plassmann et al., 2007), as well as regions of MPFC implicated in general reward processing ($x, y, z = 0, 44, 12$; van den Bos, McClure, Harris, Fiske, & Cohen, 2007) and dehumanized perception ($x, y, z = -9, 50, -2$; Harris & Fiske, 2006). We drew ROIs from these coordinates using a conservative spherical 5 voxel spread in each dimension, extracted beta weights, and entered computed *t* tests and omnibus ANOVAs.

Results

There were no differences based on player or participant gender, ethnicity, or age. As a result, all reported results are robust regarding demographic variables.

Purchasing Strategies

Participants purchased five players from the time estimation labor market before participating in the fMRI scan. We observed a variety of purchasing strategies from participants (standard deviation of the five purchased players' prices ranged from \$0.52 to \$3.03, mean standard deviation = \$1.68). Some participants purchased five average priced players, allocating their money relatively equally on five players of average skill or time estimation ability (resulting in a lower standard deviation of purchased players' prices). Other participants purchased a combination of high and low priced players, adopting a strategy where they purchased players of low and high skill or time estimation ability (resulting in a higher standard deviation of purchased players' prices). Given that the income available to each participant was fixed, reward and feedback did not differ as a result of purchasing strategy (see below). We examined whether these different purchasing strategies resulted in differences in participants' profit from randomly selected trials at the end of the study. We find that participants who purchased players with both high and low time estimation skill ($n = 13$) earned marginally more than those who purchased all players of average time estimation skill, $n = 14$, $t(25) = 1.75$, $p = .092$, $M_{diff} = \$3.34$.

However, these different purchasing strategies did not affect the number of correct trials participants viewed in the scanner (i.e., the different purchasing strategies did not lead to different experiences in the scanner) because we equated price with accuracy. Despite all outcomes viewed in the scanner being real outcomes from the players' previously recorded behavior, we designed the study such that all participants, regardless of their purchasing strategy, would see correct outcomes from their purchased players about 50% of the time. This is because price was matched to players' skill or time estimation accuracy and participants were required to purchase five players from a limited endowment of \$25. Hence the average price was approximately \$5 for each participant regardless of purchasing strategy ($M = \$4.88$, $SD = \$0.22$) making all participants' purchased players on average correct about 50% of the time.

Revaluation Behavior

While in the fMRI scanner, participants viewed outcomes from purchased and nonpurchased players' time estimation accuracy and were asked to revalue the players, indicating whether the original price should be less, the same, or more, and if different by how much (ranging from 10% to 40%). We calculated how often participants revalued purchased and nonpurchased players after accurate and inaccurate outcomes. We find that participants are more likely to revalue purchased players after accurate versus inaccurate performance, but there were no performance dependent differences in revaluation for players that had not been purchased, $F(1, 26) = 18.52$, $p < .001$, partial $\eta^2 = 0.42$, suggesting that positive or negative performance drives player revaluation only for purchased players (see Figure 2). This behavior interestingly only occurs in response to players that first elicit a dehumanized brain response (see below).

Neuroimaging Results

We focused our imaging analyses on addressing whether a dehumanized brain response occurs to purchased players and whether this response is functional for subjective valuation processes. We performed a whole brain contrast (purchased players > nonpurchased players) during Screen 1 (person perception screen) when participants were viewing the player picture. To correct for multiple comparisons, we used a false discovery rate correction, q = 0.001 $c(V) = \ln(V) + e$, resulting in eight separable clusters (see Table 1). Consistent with our hypothesis, brain imaging results show reduced activity in the social cognition brain network when participants first observe the faces of their purchased players relative to nonpurchased players (see Figure 3).

To test whether this dehumanized brain response is functional for facilitating engagement of brain regions implicated in valuation, we created a dehumanization brain index from our contrast described above. This index is defined as the extent to which a person decreases activity in these social cognition brain regions when viewing purchased compared with nonpurchased players. We tested whether this dehumanization brain index predicts activity in a region of MOFC previously implicated in valuation (Lin et al., 2012). We find that this decrease does predict brain activity in MOFC during later subjective valuation ($\beta = -.45$, $F(1, 25) = 6.24$, $p = .019$, Adj. $R^2 = .17$, suggesting this dehumanized brain response may serve some functional purpose.

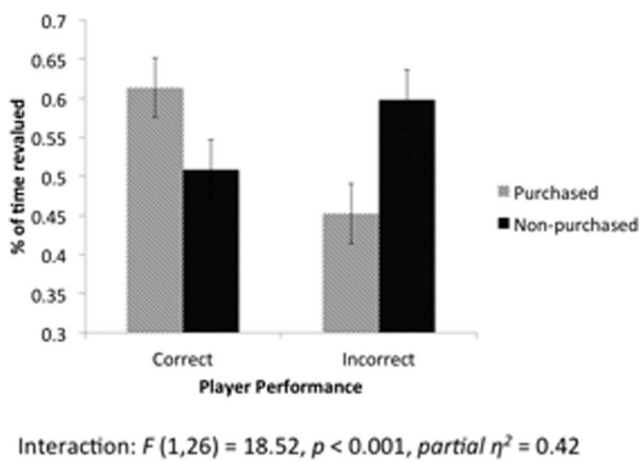

Figure 2. *Revaluation Behavior*. Bar graphs depicting participants' revaluation behavior for purchased and nonpurchased players. Error bars reflect standard error.

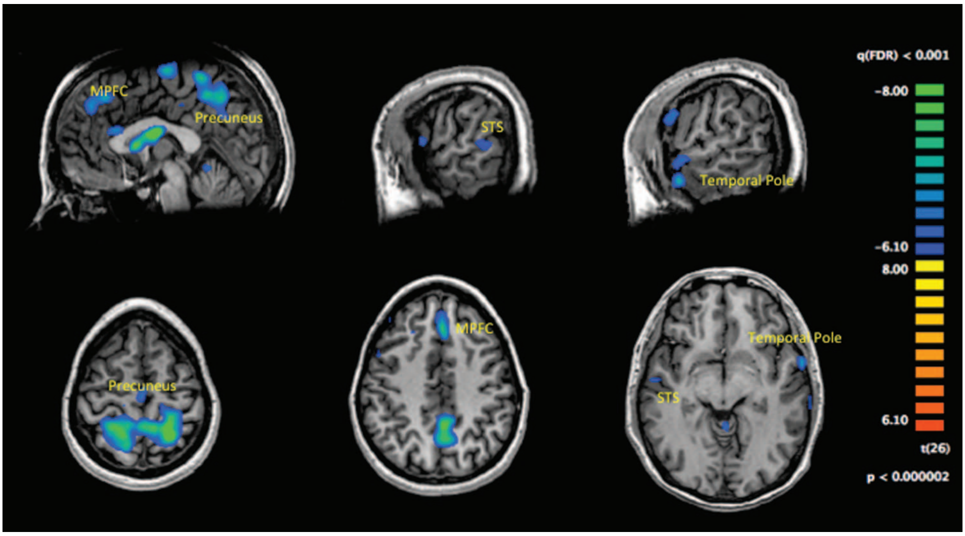

Figure 3. *Dehumanization Brain Response*. A whole brain contrast (purchased > nonpurchased) shows reduced activity in social cognition brain regions while viewing purchased players' pictures. Data were corrected for multiple comparisons using a false discovery rate of q = .001, c(V) = ln(V) + e. The heat map illustrates whether a brain region is more (warm colors) or less active (cool colors) to the contrast.

Furthermore, we tested whether activity at Screen 1 toward purchased and nonpurchased players predicts the extent to which a player was revalued at Screen 4 (i.e., participants' revaluation behavior). We created a revaluation index ranging from −4 (representing a decrease of the player's price by 40%) to +4 (representing an increase in player's price by 40%) where 0 represents keeping the player's price the same. This revaluation index was entered into a linear regression with the mean beta weights to purchased and nonpurchased players (separately) at Screen 1 as our predictor. Consistent with the pattern of behavior reported above, we find separable valuation systems for purchased and nonpurchased players. Initial brain responses in the social cognition network (Screen 1) to purchased players predict later revaluation behavior for those players, $\beta = -.39$, $F(1, 25) = 4.59$, $p = .042$, Adj. $R^2 = .12$ (see Figure 4a). We do not observe a similar finding for nonpurchased players, $\beta = -.19$, $F(1, 25) = .91$, $p = .348$, Adj. $R^2 = .003$ (see Figure 4b). Instead, activity in value MOFC regions during valuation (Screen 4; Lin et al., 2012; Plassmann et al., 2007) together marginally predict later revaluation to nonpurchased players, $\beta = .36$, $F(1, 25) = 3.65$, $p = .067$, Adj. $R^2 = .09$ (see Figure 4d). We do not observe a similar finding for purchased players, $\beta = .28$, $F(1, 25) = 2.17$, $p = .153$, Adj. $R^2 = .04$ (see Figure 4c).[1]

Secondary Region of Interest (ROI) Analyses

We examined ROIs in MOFC previously implicated in willingness-to-pay ($MOFC_{wtp}$; Plassmann et al., 2007) and reward processing ($MOFC_{rwd}$; Lin et al., 2012), as well as ROIs in

[1] All data points on all four regressions are within limits to not be considered outliers, including Mahalanobis distance (all data points < 11.25), and Cook's distance (all data points < .55), suggesting the use of linear regression and a Pearson's r coefficient reliably describe the relationship between variables. However, we also ran robust correlations (Pernet, Wilcox, & Rousselet, 2013) on our two significant and marginal relationships, using $\alpha = .025$ corrected for multiple comparisons. We found that our significant relationship between social cognition brain index activity and the revaluation index for purchased players becomes marginal; percent-bend coefficient $r = -0.33$, $p = .098$, CI [−0.67, 0.07]. The marginal relationship between MOFC activity and revaluation of nonpurchased players remains marginal; percent-bend coefficient $r = .33$, $p = .091$, CI [−0.10, 0.64].

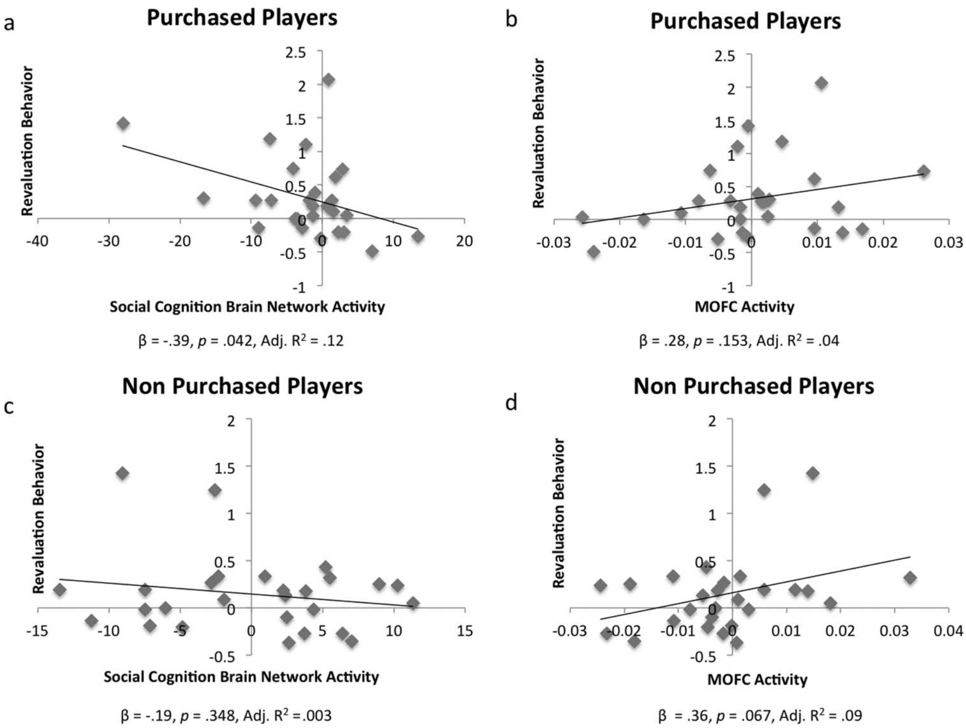

Figure 4. *Double Dissociation in MOFC*. Scatterplots illustrating the relationship between brain activity when first seeing a player and later revaluation behavior. (a) Social cognition brain network activity derived from purchased > nonpurchased players contrast at Screen 1 and revaluation behavior of purchased players. (b) Average MOFC ROIs brain activity at Screen 1 and revaluation behavior of purchased players. (c) Social cognition brain network activity derived from purchased > nonpurchased players contrast at Screen 1 and revaluation behavior of nonpurchased players. (d) Average MOFC ROIs brain activity at Screen 1 and revaluation behavior of nonpurchased players.

MPFC previously implicated in reward processing ($MPFC_{rwd}$; van den Bos et al., 2007) and a dehumanized perception response ($MPFC_{dhp}$; Harris & Fiske, 2006) at each of the three events of our trial: person perception (Screen 1), outcome (Screen 3), and revaluation (Screen 4). We did not have any specific interest in brain activity when participants viewed the target time (Screen 2) because this screen was only provided to give participants a context for the positive and negative outcomes during Screen 3. We chose these specific ROIs to explore the brain response to purchased and nonpurchased players throughout our task beyond our initial hypotheses. We expect findings to confirm the ascribed function of these regions based on previous studies in the literature, serving as manipulation checks that our paradigm replicated previous findings in the reward processing and dehumanized perception literatures.

During person perception (Screen 1), we observed a significant difference in $MPFC_{rwd}$, $t(26) = -2.13$, $p = .043$ such that there was more activity to nonpurchased than purchased players ($M_{diff} = -.05$). There were also similar marginally significant differences in $MPFC_{dhp}$, $t(26) = -1.89$, $p = .070$, $M_{diff} = -.04$ and $MOFC_{wtp}$, $t(26) = -1.76$, $p = .091$, $M_{diff} = -.04$. These results are consistent with the whole brain contrasts reported above and the predictions based on the dehumanized perception literature.

During outcome (Screen 3), we observed a significant main effect of *outcome* (correct/incorrect) in both $MPFC_{rwd}$, $F(1, 26) = 4.56$, $p = .042$, partial $\eta^2 = .15$, $\Omega = .54$, and

MOFC_{rwd}, $F(1, 26) = 4.55$, $p = .043$, partial $\eta^2 = .15$, $\Omega = .54$, such that there was greater activity to incorrect (MPFC_{rwd} $M = .002$; MOFC_{rwd} $M = -5.56\text{E-}05$) than correct responses (MPFC_{rwd} $M = -.004$; MOFC_{rwd} $M = -.007$). These results suggest that regions previously implicated in reward processing are more engaged by incorrect feedback for all players, purchased or not, and are consistent with the reward processing literature.

During revaluation (Screen 4), we found a significant *value* (less, more) × *player* (purchased, nonpurchased) interaction in MOFC_{rwd} $F(1, 26) = 5.27$, $p = .030$, partial $\eta^2 = .17$, $\Omega = .60$). This interaction was qualified by a simple effect difference such that there was more activity when increasing rather than decreasing purchased players' value, $t(26) = -2.29$, $p = .030$, $M_{diff} = -0.02$. There was also a simple effect difference such that there was less activity when decreasing purchased rather than nonpurchased players' value, $t(26) = -2.27$, $p = .032$, $M_{diff} = -.01$. These results suggest that decreasing purchased players' values engaged this region implicated in reward processing less. We also found a significant *value* main effect in MPFC_{rwd}, $F(1, 26) = 5.22$, $p = .031$, partial $\eta^2 = .17$, $\Omega = .60$, such that this region is more active when participants decreased ($M = -2.78\text{E-}04$) rather than increased player value ($M = -.005$). The dissociation between results in brain regions implicated in reward processing in the MPFC and MOFC suggests distinct functions for each brain region during social revaluation.

Discussion

To investigate the brain mechanisms underlying economic valuation of people, we created a labor market of time estimation players and allowed a separate group of participants to purchase and revalue members of this market while in the scanner. We confirm our hypothesis that purchasing and assigning economic value to people results in a dehumanized brain response. This dehumanized perception, indexed by reduced activity in the social cognition brain network, facilitates engagement of valuation brain regions during revaluation of purchased players. Furthermore, our results suggest a double dissociation; activation in social cognition brain regions modulates revaluation behavior toward purchased players (where participants are outcome dependent on the performance of the player), whereas activation in MOFC modulates revaluation behavior toward nonpurchased players (where participants are not dependent on the performance of the player). These results are consistent with the dehumanized perception literature, showing that everyday human targets can be dehumanized if the context encourages it (Harris & Fiske, 2006, 2011). Here the context—ownership of purchased players in an economic labor market—results in reduced activity in the social cognition brain network when viewing these people as commodities.

As with any other commodity, it would be advantageous for a buyer to accurately assign subjective value to another person, ensuring that the buyer does not overpay for him or her. Without a dehumanized perception, this valuation process may be hindered when inferring a person's mental state and may also prevent learning in the context of an economic market. Our behavioral results support this notion, as we observed performance dependent differences in revaluation behavior for purchased players but not for nonpurchased players. Perhaps the dehumanized perception response observed for purchased players allows participants to be more responsive to positive and negative outcomes. However, we remain agnostic as to whether participants intended to engage a dehumanized perception or not. Perhaps the described brain patterns reflect unintentional, nonconscious processing governed by context. Future research is necessary to determine the extent to which a dehumanized perception brain response can be intentional.

One possible interpretation of our brain imaging results is novelty seeking (see Cohen, Schoene-Bake, Elger, & Weber, 2009; Wittman, Daw, Seymour, & Dolan, 2008, for similar results); perhaps participants were more engaged by photographs of nonpurchased players than purchased players, resulting in more MPFC activity to the former. We can rule out this alternative explanation because participants saw photographs of all the players, not simply purchased players, before entering the scanner. Therefore, it is highly unlikely that the nonpurchased players were in any way novel. Moreover, the large social neuroscience literature on dehumanized perception supports the interpretation of the findings (see Harris & Fiske, 2009 for a review).

Participants in our study may have revalued as a way of punishing or rewarding the players; otherwise revaluation behavior in the context of our paradigm is irrational. Because initial price is tied to accuracy and participants are fully aware of the accuracy/price of each player (purchased and not), participants should expect outcomes consistent with the player's price, even for players with high values. Granted, an expensive player has a low likelihood of incorrect performance, and trials in which an expensive player was incorrect may violate the participants' expectations. However, because participants see multiple trials from each player, over time, even such a player's performances will average to their overall accuracy/price. Hence revaluation is irrational and unnecessary because participants are simply seeing the previous performance of the players. We purposefully designed our experiment in this manner to allow for a clear indicator of irrationality: revaluation behavior. The fact that we see differences in this behavior based on whether the player was purchased or not suggests different reactions to feedback to the two types of players, and different instances when participants are more likely to be irrational.

It is also possible to establish a benchmark for rational decisions for revaluation with the economic formula $P = A + w * (O * F)$, where P represents the revalued price of the player, A represents the player's overall accuracy, O represents whether the participant purchased the player or not, F represents whether the player was correct or incorrect in their time estimation performance on a specific trial, and w represents the weight placed on these variables during revaluation. Because we equated initial price with accuracy, $O * F$ determines whether a participant increases or decreases a player's value, that is, whether the sign is positive or negative. A rational actor, aware that price and accuracy are equated, would simply assign zero values to w because the observed player's performance on a given trial already factors into accuracy and price, and ownership of a player or not should not determine the player's value. However, research on the endowment effect suggests that ownership of goods increase their subjective value (Thaler, 1980). Moreover, negative feedback looms larger than positive feedback (Kahneman & Tversky, 1979), as is the case in loss aversion, suggesting that the player's trial-by-trial performance may affect the value assigned to that player. Thus, most participants are not likely to assign zero values to w, resulting in revaluation of the players based on whether they were purchased as well as their performance. Given that $P = A$, $w * (O * F)$ should equal to zero on trials where a player's value remains unchanged. On trials where the value was changed, we solved for $w * (O * F)$ and regress these values on brain data. We did not find any significant results when applying this economic formula to our brain data, suggesting perhaps the formula needs to be further specified.

The results of this study also contribute to the growing literature on the function of the MPFC. Although social neuroscience has implicated MPFC in social cognition (Beer, John, Scabini, & Knight, 2006; Van Overwalle, 2009) and neuroeconomics has focused on MPFC in valuation (Lin et al., 2012), few studies (Harris, McClure, van den Bos, Cohen, & Fiske, 2007; van den Bos et al., 2007) have combined these literatures to understand how these processes may interact. In this study, we delineate a process by which subjective value and person perception processes may interact within MPFC to allow agents dealing with labor markets to effectively value people as commodities. By reducing activity in social cognition brain regions, agents can engage valuation processes typically applied to humans. Psychologically, it may be useful to engage strictly reward processing mechanisms (valuation) for members of a labor market because automatic person perception mechanisms (social cognition) may hinder subjective valuation.

Participants behave irrationally within the context of our time estimation league; they revalue other people when witnessing past performance that determined price, where price is tied to accuracy. Specifically, our findings indicate that when people were purchased, and participants were outcome dependent on their performance, brain regions sensitive to relative differences between groups of people (Cikara, Eberhardt, & Fiske, 2011; Harris & Fiske, 2006; Harris et al., 2007) predicted later, irrational revaluation behavior. Traditional value regions, implicated in a variety of objects of value (Lin, Adolphs, & Rangel, 2012; Litt et al., 2011;

Plassmann, O'Doherty, & Rangel, 2007) did not predict this irrational behavior. However, when people were not purchased, these traditional valuation brain regions did predict the irrational revaluation behavior, and the brain regions that relatively valued groups of people did not predict the irrational behavior. This suggests that the economic act of purchasing and subsequently being outcome dependent on performance, as may occur for any other commodity, relies on relative valuation processes in a separable brain system.

Empathy and the resulting moral responsibility to treat others ethically may contradict motivations to exploit people via subjective value assignment. A dehumanized perception brain response may have a functional purpose within the context of economic markets where people are the commodities. Together, these results suggest that dehumanized perception may be functional and useful in profit-maximizing contexts common in capitalist societies. This implicates a role for relative social valuation and social cognition in economic markets.

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