

Economic principles motivating social attention in humans

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We know little about the processes by which we evaluate the opportunity to look at another person. We propose that behavioural economics provides a powerful approach to understanding this basic aspect of social attention. We hypothesized that the decision process culminating in attention to another person follows the same economic principles that govern choices about rewards such as food, drinks and money. Specifically, such rewards are discounted as a function of time, are tradable for other rewards, and reinforce work. Behavioural and neurobiological evidence suggests that looking at other people can also be described as rewarding, but to what extent these economic principles apply to social orienting remains unknown. Here, we show that the opportunity to view pictures of the opposite sex is discounted by delay to viewing, substitutes for money and reinforces work. The reward value of photos of the opposite sex varied with physical attractiveness and was greater in men, suggesting differential utility of acquiring visual information about the opposite sex in men and women. Together, these results demonstrate that choosing whom to look at follows a general set of economic principles, implicating shared neural mechanisms in both social and non-social decision making.

Keywords: attractiveness; neuroeconomics; temporal discounting; social neuroscience

1. INTRODUCTION

Adaptive social behaviour clearly benefits from information about other individuals (Anderson 1998; Ghazanfar & Santos 2004). Strategically beneficial information may include a rival's fighting ability (Tibbetts & Dale 2004), a potential ally's social status (Deaner *et al.* 2005) or the genetic fitness of a potential mate (Rhodes 2006). People appear to value visual information about others, since they pay to view celebrities and models in magazines and movies even though they are unlikely to ever meet them. Numerous studies have revealed that people preferentially look at the faces of others in photographs (e.g. Yarbus 1967), that such preferences emerge early in human infancy (Morton & Johnson 1991), and that viewing faces activates brain structures that also respond to rewards such as food and money (Aharon *et al.* 2001; O'Doherty *et al.* 2003; Winston *et al.* 2007). Disruptions in processing the normal valuation of social stimuli may even contribute to dysfunctional social behaviour in neurological disorders such as autism, social anxiety, schizophrenia and anorexia (Deldin *et al.* 2000; Pelphrey *et al.* 2002; Baron-Cohen & Belmonte 2005; Langdon *et al.* 2006).

Such observations suggest the hypothesis that viewing other individuals serves as a reward similar to others such as food, drink or money. If this is the case, decisions about whether or not to look at another person should obey the same principles that guide decisions motivated by other types of rewards. A wealth of research in economics and experimental psychology has identified several core characteristics of rewards. First, rewards are discounted by the delay

until they are tendered (Mazur 1987; Kirby & Marakovic 1996; Green *et al.* 1997; Rachlin 2000; Frederick *et al.* 2002; Giordano *et al.* 2002; Green *et al.* 2004; McClure *et al.* 2004). Moreover, such discounting of monetary offers decreases with the size of the offer (Green *et al.* 1997). Second, different types of rewards can be traded according to an equivalence function, suggesting a common currency of valuation (Bickel *et al.* 1995; Deaner *et al.* 2005). Finally, rewards serve as incentives for work (Bickel *et al.* 1992; Hursh & Winger 1995; Aharon *et al.* 2001).

Surprisingly, almost nothing is known about how we evaluate the opportunity to look at another person (Anderson 1998; Aharon *et al.* 2001; Blatter & Schultz 2006). We hypothesized that social orienting decisions follow the same economic principles as those governing commodities such as food, drinks and money. To test this idea, first we investigated whether people discount the opportunity to view photos of others in an inter-temporal choice task. Second, we examined whether viewing images of other individuals can substitute for monetary rewards using a monetary choice task (Deaner *et al.* 2005). Finally, we assessed the incentive value of viewing images of others using an effort task (Aharon *et al.* 2001). Collectively, our results indicate that social orienting decisions obey principles remarkably similar to those underlying economic choices about food or money. These results suggest the possibility that a shared neural system mediates both social and non-social decision making.

2. MATERIAL AND METHODS

(a) Subjects

Twenty male and twenty female self-reported heterosexual adults participated in the study. All subjects were undergraduate

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or graduate students and all subjects gave informed consent. The study was approved by the Duke University Medical School Institutional Review Board. The monetary choice and effort tasks were performed in a single session that paid \$12–18, depending on decisions made in the monetary choice task. The inter-temporal choice task was performed in a separate session and paid \$10. Testing was performed on PCs using MATLAB and PSYCHTOOLBOX (Brainard 1997).

(b) Image databases

Two databases were generated containing over 2000 male and 2000 female images. All images were downloaded from the Hotornot web site (<http://www.hotornot.com>) in July 2006. This publicly accessible web site allows anyone to post a photo and receive average attractiveness ratings from the browsing public. We selected images that had only a single central subject with a clearly visible face. We eliminated photos which were blurry or small, photos with animals or displays of wealth, photos in which emotionally salient objects such as guns, snakes or motorcycles were visible, photos with subjects in provocative sexual positions or with nudity and photos in which the subjects appeared to be younger than 18 years old.

We ignored the web site's posted ratings and reassessed attractiveness in a laboratory environment. Eleven males each rated all 2000 female photographs in the female database. Eleven females each rated all 2000 male photographs in the male database. Raters were not used as test subjects in subsequent experiments. Ratings were made on a PC using a program that displayed each photo for 1 s and then waited for a rating. Raters could press a button to view each photograph again. The instructions asked raters to rate each image for attractiveness on a scale from 1 to 10.

All raw ratings were then converted to z -scores and these were then averaged to calculate a single composite rating for each photograph. Composite ratings were used to divide each database into three categories. The high attractiveness category consisted of the 100 most highly rated images in each database (mean raw score: male raters 7.4; female raters 6.89); the neutral category consisted of 200 images around the average of the distribution (mean: males raters 5.44; females raters 4.47); and the low attractiveness category consisted of the 100 lowest rated images (mean: males raters 2.92; female raters 2.38). In all tasks, male subjects viewed only photos of females and vice versa. We calculated the correlation coefficient (Pearson's r) between each pair of raters and averaged these. The average correlation between males ($r=0.49\pm 0.042$) was significantly greater (Student's t -test, $t=19.79$, $p<0.001$) than that between females ($r=0.38\pm 0.19$). Both males and females showed stronger agreement for the specific images that were actually used in the experiments ($r=0.68\pm 0.047$ for males and 0.49 ± 0.09 for females) than for the entire database.

(c) Inter-temporal choice task

Subjects were seated at a computer in a private room and were read instructions from a script. Two targets appeared on each trial (figure 1a). Below each target was displayed information about the delay, duration and attractiveness of the set of photos offered for viewing on that trial. One target (shorter/sooner, SS) offered an immediate 1 s presentation of a photo; the other target (longer/later, LL) offered a delayed (0.5, 1, 10 or 30 s) presentation of a photo for a variable duration (1, 1.1, 3, 5 or 8 s). Subjects were required to select one of the targets. The attractiveness of the photo was

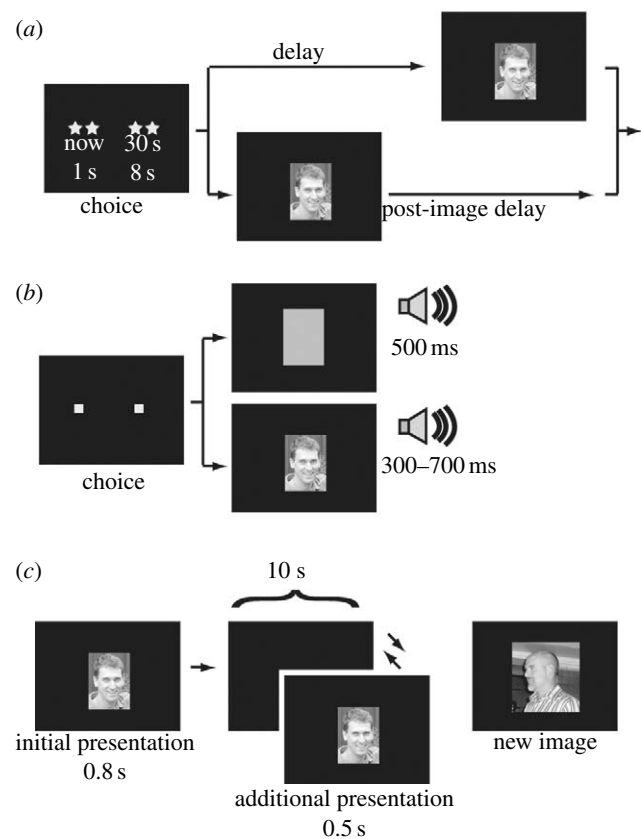


Figure 1. Tasks used to assess economic principles underlying social attention. (a) Inter-temporal choice task. Subjects were given a choice between seeing an image for 1 s immediately (shorter/sooner, SS option) and seeing an equivalently attractive image for a longer duration in the future (longer/ later, LL option). The number of stars for each option indicated attractiveness of image that would be shown if that option was selected. Delay following image was dynamically modified so that average image presentation rate remained constant. (b) Monetary choice task. Subjects were given a choice between a constant target and a variable target. Choice of constant target was followed by presentation of a grey square and a 500 ms sound. Choice of variable target was followed by presentation of a photo (attractiveness was changed in 100 trial superblocs) and a sound of 300–700 ms (duration was changed in 20 trial blocks). (c) Effort task. Subjects were briefly presented with a photo and then the screen went blank. Subjects could perform effort task (pressing space bar and F key with one finger in sequence) to obtain another brief view of the same image. Trial lasted 10 s and was immediately followed by a new trial.

indicated with stars; both targets offered identical attractiveness levels on each trial. The location of the LL and SS and the attractiveness of the two options were varied randomly on each trial. Selection of either target was followed by presentation of a photo drawn from the offered category at the offered delay and for the offered duration. Presentation was followed by a variable delay chosen so that the average trial length was identical whether the LL or SS image was chosen, and this fact was mentioned in the instructions. This method eliminated a possible confound of different reward rates for the two options.

(d) Monetary choice task

Subjects were seated at a computer and were read instructions from a script. Two targets were presented on each trial (figure 1b). One target (constant target) led to

presentation of a grey square and a 500 ms sample of a sound (a wav file of money pouring into a slot machine). The other target (variable target) led to presentation of a photograph and a sample of the same sound for a variable (300, 400, 500, 600 or 700 ms) duration. Sound duration was kept constant throughout 20 trial blocks. Photo attractiveness was kept constant in 100 trial superblocks. Blocks occurred in random order within the superblock and four superblocks (attractive, unattractive and two neutral) occurred in random order in the session. Subjects were guaranteed \$10 for participation, but could earn additional money based on performance. Each trial offered a bonus that depended linearly on the sound duration (300 ms: 3 cents; 400 ms: 4 cents; 500 ms: 5 cents; 600 ms: 6 cents; 700 ms: 7 cents). Cumulative earnings were presented 20 times, once at the end of each 20 trial block.

(e) Effort task

Subjects were seated at a computer and were read instructions from a script. On each trial, a photo was shown for 0.8 s followed by a 10 s blank period (figure 1c). By pressing the space bar and one of the function keys (F5, F6, F7 or F8), the subject could cause the photo to reappear for another 0.5 s. To make the task more difficult, subjects were instructed to use only one finger. After 10 s, the trial ended, a brief tone was played and a new trial began with a new photograph. The task consisted of 100 trials with no break. Photographs were selected at random from the three categories and appeared in a random order.

(f) Analysis

Hyperbolic discount parameters (Mazur's 1987, k -value) were calculated for each subject in each attractiveness condition. The procedure estimated indifference points and was analogous to the one used in a previous monetary discounting study (Kirby & Marakovic 1996). In essence, the method is similar to a game of Twenty Questions with a single dimension and noisy answers. The discount function was assumed to have the form $v' = v/(1 + kD)$, where v' indicates discounted image utility; v indicates image utility (assumed to depend linearly on duration of photo display); k is the discount parameter; and D is the delay. Each choice (two delay/duration pairs) was associated with a characteristic discount parameter by the function $k = (\text{LL duration} - 1)/\text{LL delay}$. Selection of the LL target indicated that the discount parameter was lower than this choice's characteristic discount parameter; and selection of the SS target indicated that the discount factor was greater. The point at which each subject's choices switched from LL to SS gave the estimate of their discount parameter.

We distinguished performance from random guessing with a bootstrap method (implemented in MATLAB). The average k -values for the SS and LL options were calculated, and then the sequence of decisions was randomized 1000 times; then randomized SS and LL means were calculated. Behaviour was taken to show a significant discounting effect if it fell below the 25 lowest bootstrap values ($p < 0.05$, two-tailed t -test). Standard errors for each subject were estimated using a jackknife procedure. The dataset was subsampled with 10% of the data excluded 10 times, and the average variance was computed. The jackknife standard error was defined as the jackknife standard deviation multiplied by the square root of the number of samples minus 1, i.e. nine (Efron & Tibshirani 1993).

Points of subjective equivalence (PSE) were calculated for each subject for each set of photographs (attractive, neutral and unattractive). The PSE was calculated by fitting choice frequencies with a standard cumulative normal function (Deaner et al. 2005). This function is characterized by two parameters, the mean μ and the standard deviation σ . All analyses were repeated with an additional variable asymptote parameter to adjust for ceiling and floor performance; the results were qualitatively identical to those reported here without the asymptote. Visual inspection confirmed that performance was well fit at the extremes. Fitting was performed using a gradient descent and by a least squares procedure. The PSE was taken as the point where the cumulative normal distribution crossed the neutral ($p = 0.5$) line. Image value was computed as the sign-reversed PSE. Standard errors were calculated using a jackknife method as mentioned earlier.

We estimated the relationship between effort and attractiveness by calculating the slope of the best-fit line through the data. The best-fit was defined as the line that minimized the average square difference between the line and the points. Significance was assessed using a bootstrap method; the values were randomized 1000 times and new best-fit lines were calculated. The slope of the line was taken to be significantly positive, if it was greater than the 25th steepest randomized line ($p < 0.05$, two-tailed t -test).

3. RESULTS

In the inter-temporal choice task, most subjects (90%: 18/20 males, 18/20 females; $p < 0.05$, bootstrap significance test) discounted the opportunity to view images of the opposite sex when either delay increased or viewing duration decreased. Males were significantly more patient when choosing to view attractive females than they were when choosing to view neutral or unattractive females ($t = 2.6$, $p = 0.02$; figure 2), but females showed no effect of male attractiveness on discounting ($t = 0.88$, $p = 0.4$). These results suggest that, for men, the reward value of seeing a woman is strongly influenced by physical attractiveness, but for women physical attractiveness has little or no impact on visual reward value. These results are consistent with other studies reporting a greater importance of physical attractiveness for men (Buss & Schmitt 1993; Landolt et al. 1995; Aharon et al. 2001; Baumeister et al. 2001).

Temporal discounting of images of the opposite sex suggests that visual social information, primary rewards like food and abstract rewards like money are evaluated by similar mechanisms that are sensitive to delay. If this is the case, then there should also be a reliable trade-off between money and the opportunity to see images of the opposite sex, just as there is between monetary rewards and other rewards such as food and drink. We estimated the value of seeing images of the opposite sex by the amount of bias they evoked in a monetary choice task (figure 3; Deaner et al. 2005). We calculated specific values for the ratings for each subject and performed a two-factor ANOVA on this data. The ANOVA revealed significant effects for value and gender ($p < 0.05$ in both cases), and a significant interaction between the two ($p < 0.05$).

We found that males strongly valued the opportunity to view attractive females (0.45 cents each, $p < 0.05$), slightly valued images of neutral females (0.19 cents each, $p < 0.05$) and found images of unattractive females

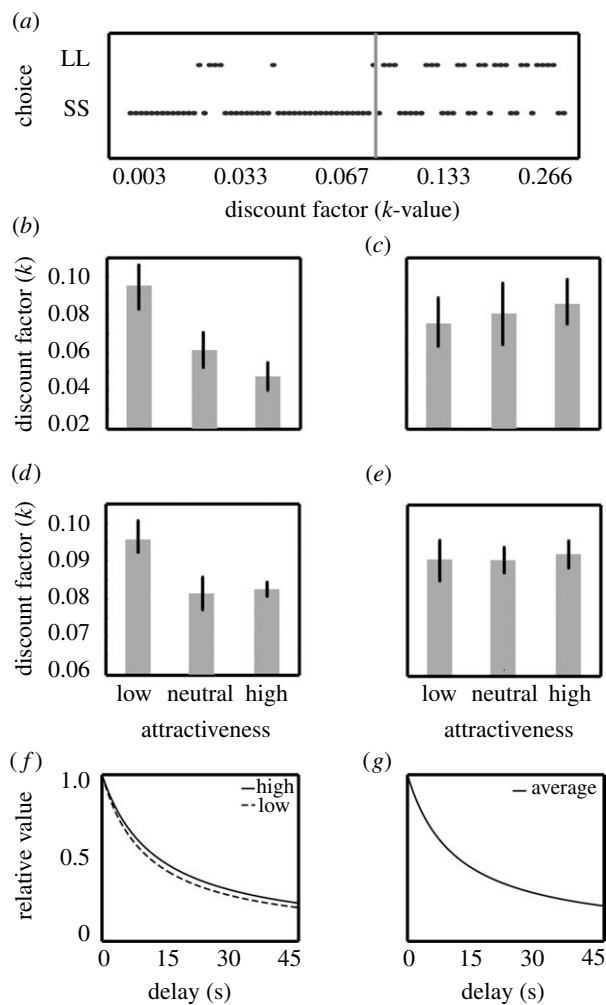


Figure 2. Reward value of images of the opposite sex is discounted by delay. (a) Choices made by one subject in inter-temporal choice task. Each dot represents a single choice; horizontal axis indicates discount factor associated with the pair of options. When the delayed option was only marginally longer than the immediate option (left side of graph), the subject preferred the immediate (SS) option. The crossover point determines the best-fit hyperbolic discount factor (Mazur's k -value) for the subject. For illustrative purposes, data from all attractiveness conditions are combined in (a) only. (b) Discount factors for a single male subject in three attractiveness conditions. This subject discounted the opportunity to view attractive images less steeply (i.e. lower k -value) than unattractive ones. This effect is analogous to the magnitude effect for monetary discounting. Error bars indicate ± 1 s.e. (c) Hyperbolic discount factors for a single female subject (same format as in (b)). Attractiveness did not influence discount factor for this subject. (d) Average hyperbolic discount factors for all males in population ($n=20$, same format as in (a)). Males discounted the opportunity to view attractive and neutral images less steeply than they did unattractive images. (e) Average hyperbolic discount factors for all females in the population ($n=20$). Attractiveness did not influence discount factors. (f) Hyperbolic curve showing average relative value of delayed opportunity to view attractive (solid) and unattractive (dashed) images as a function of delay until presentation for all males. Value of image decreases with time. (g) Hyperbolic curve showing discounted value of delayed opportunity to view image relative to immediate viewing for all females in the population (only the average of the attractive and unattractive conditions is shown, since the individual curves overlap).

mildly aversive (-0.07 cents each, $p>0.05$). In comparison, females slightly valued images of attractive males (0.05 cents each, $p>0.05$), were indifferent to images of neutral males (0.02 cents each, $p>0.05$), and found images of unattractive males strongly aversive (-0.18 cents each, $p<0.05$). Within each class of physical attractiveness, males valued images of the opposite sex more than females did ($p<0.05$ in all three cases). Collectively, these results demonstrate that viewing images of members of the opposite sex can substitute for monetary rewards and, moreover, that the reward value of seeing a face depends on its physical attractiveness and one's own gender.

If seeing people does function as a reward, it should also reinforce work. To test this idea, we measured whether men and women would be motivated to press keys on a keyboard to view a photograph (figure 4). On average, males worked twice as hard as females did (Student's t -test, $t=12.6$, $p<0.001$). Both males and females showed a statistically significant correlation between effort and image attractiveness ($p<0.001$ in both cases, bootstrap regression test), but this correlation was stronger for males than for females (t -test on best-fit slopes, $t=12.6$, $p<0.0001$). These data indicate that the opportunity to view the opposite sex serves as an incentive for work, and that both physical attractiveness of the photograph and one's own gender influence incentive value.

4. DISCUSSION

Our results indicate that standard economic principles apply to social orienting decisions, just as they apply to decisions about appetitive and monetary rewards. Using this framework, we made several new discoveries. First, the value of a photograph of the opposite sex is discounted by the delay until it appears and is proportional to viewing duration. Second, physical attractiveness influences discounting of social images in males. Specifically, males show more patience when choosing to view physically attractive females than when choosing to view physically unattractive females. Third, viewing images of the opposite sex substitutes for monetary rewards, and this valuation scales with physical attractiveness. Finally, people will work to view images of the opposite sex and will exert more effort for more attractive photos. Collectively, these results demonstrate that the opportunity to look at another person is a valued commodity and that physical attractiveness is one dimension along which value varies.

Our results show that males work nearly twice as hard as females to view photos of equivalent attractiveness, and will forego significantly more money to view them as well. These results endorse the ideas that simple ratings do not provide a strong predictor of reward value (Aharon *et al.* 2001), and that econometric methods, which rely upon the principle of revealed preference, can provide a more accurate measure of valuation. Furthermore, across all the three experiments, males exhibited greater sensitivity to physical attractiveness than females did. These results are consistent with the evolutionary hypothesis that physical attractiveness plays a stronger role in mating decisions for men than for women (Buss & Schmitt 1993; Landolt *et al.* 1995; Aharon *et al.* 2001; Baumeister *et al.* 2001). The wide discrepancy in valuation of images by the two sexes distinguishes social images from other goods, such as

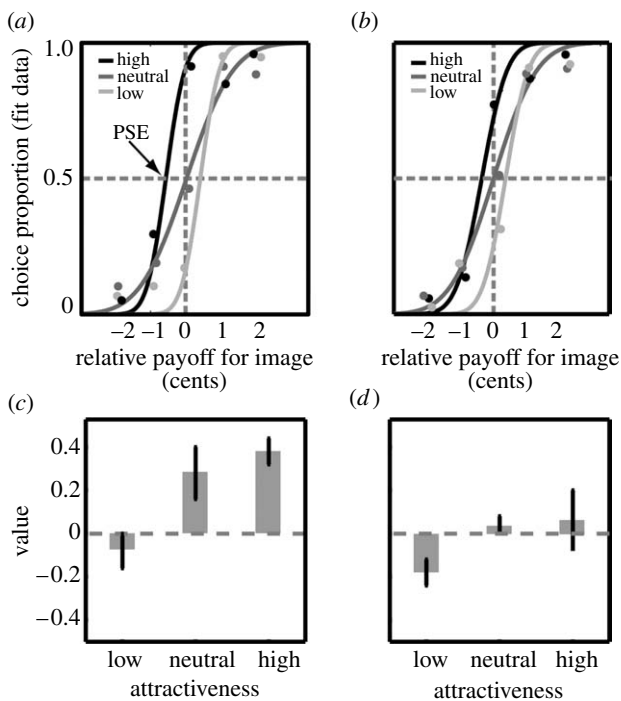


Figure 3. People implicitly substitute images of the opposite sex for money. (a) Performance of a single male subject in the monetary choice task showing both raw data (dots) and best-fit cumulative normal functions (lines). This subject preferred the higher-paying option, but his decisions were influenced by the attractiveness of the photos displayed. The point at which the best-fit line crosses the neutral line (point of subjective equivalence, PSE indicated for high attractiveness images by arrow) shows the subjective value of the opportunity to see the photograph. This subject valued seeing attractive photos, was indifferent to neutral photos, and required payment to see unattractive photos. Points are jittered on *x*-axis to facilitate interpretation. (b) Performance of a single female subject in the monetary choice task (same format as in (a)). This subject showed a similar behavioural pattern as the example male subject, but with weaker effects. (c) Average PSEs for all males ($n=20$), expressed in terms of equivalent monetary price (US cents). Males valued the opportunity to view attractive and neutral females, but required a small (non-significant) payment to view unattractive females. Bars indicate 1 s.e., estimated by jackknife (§2). (d) Average PSEs for all females in population ($n=20$, same format as in (c)). Females did not significantly value the opportunity to view attractive and neutral males, and required a payment to view unattractive males. Females showed lower average PSE than males ($p<0.05$) and their PSEs showed less dependence on attractiveness than males ($p<0.05$).

money and food, which have approximately similar value functions for men and women. One possible confound is that the weaker correlations among female raters led to weaker apparent effects in the tasks. Although this is a possibility, the relatively high degree of agreement among female raters makes it unlikely that this fully accounts for the patterns reported here.

Most prior studies of delay discounting have probed temporal devaluation of money in humans, and food and drinks in animals. Both avenues of research have determined that hyperbolic (or similar) curves best describe discounting, yet two major discrepancies remain. First, animals are more impatient than humans. This discrepancy may reflect either differences in the types of

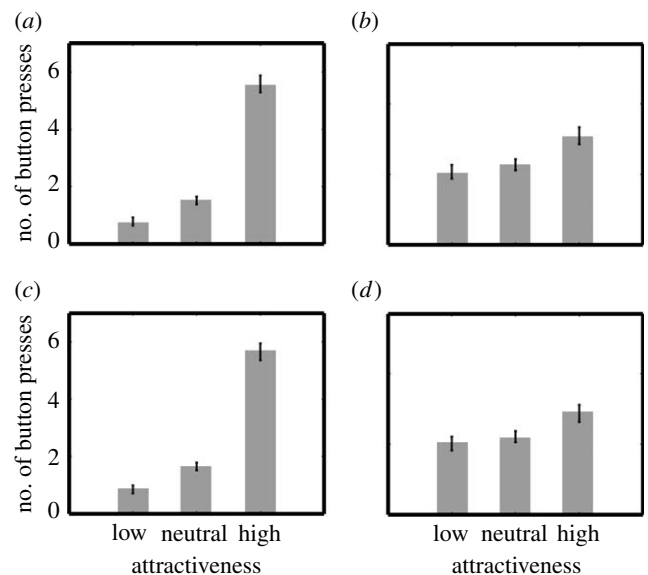


Figure 4. People will work to view the opposite sex. (a) Number of times effort task (pressing keys on keyboard) is performed for images in each attractiveness level for one male subject. Attractiveness influenced reinforcing value of images ($p<0.0001$). (b) Effort task performance for single female subject (same format as in (a)). Although attractiveness influenced reinforcing value of the images ($p<0.01$), the amount of work elicited was smaller than for the male subject ($p<0.001$). Axis is expanded relative to (a) to illustrate the trend. (c) Effort task performance for all male subjects ($n=20$). Males worked harder for more attractive images ($p<0.001$). (d) Effort task performance for all female subjects ($n=20$). Although attractiveness reinforced the reinforcing value of the images ($p<0.001$), the amount of work elicited was smaller than for male subjects ($p<0.001$). Axis is expanded relative to (c) to illustrate the trend.

reward used in such studies or a true species difference in patience. The discount factors we report here for viewing images are much higher than those normally obtained for monetary rewards in people, but are approximately the same as those obtained in animals working for food and drinks (Mazur 1987). These results suggest that differences in discounting reported for humans and other animals depend on the rewards themselves. This idea, in turn, supports the intuitive notion that the opportunity to view images of the opposite sex is treated as a consumable commodity by the brain.

The second discrepancy found in previous studies is that people discount monetary rewards less when the stakes are larger, but no evidence for such a magnitude effect has been reported in animals (Green *et al.* 2004). Our finding of decreased impulsivity in males choosing to view physically attractive females is the first demonstration of a magnitude effect for a non-monetary reward in any species. This finding suggests that the magnitude effect is not limited to abstract rewards. We believe that it is premature to conclude that failures to observe the magnitude effect among animals reflect something unique about humans; in fact, our discounting paradigm could easily be used to determine whether the magnitude effects are observed for visual social rewards in animals.

Our findings imply that a shared valuation system mediates both social and non-social decision making. This system may be disrupted in certain neurological disorders, such as autism, schizophrenia and depression, that are

characterized by both social and non-social deficits in behavioural valuation (Deldin *et al.* 2000; Pelphrey *et al.* 2002; Baron-Cohen & Belmonte 2005; Langdon *et al.* 2006). For example, social orienting deficits in autism may result, in part, from a failure to assign appropriate motivational valence to faces. Such breakdowns in assigning motivational value to social information in neurological disorders highlight the clinical importance of fully elucidating the neural mechanisms underlying socially motivated orienting.

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