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Symmetry in Cold-to-Hot and Hot-to-Cold Valuation Gaps

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Abstract
Individuals commonly mispredict their future preferences when they make decisions in a visceral state different from their anticipated state at consumption. In the research reported here, we asked subjects to bid on different foods while exogenously varying their hunger levels at the time of decision and at the time of consumption. This procedure allowed us to test whether cold-to-hot and hot-to-cold gaps are symmetric in size and driven by similar mechanisms. We found that the effect size was symmetric: Hungry subjects overbid 20¢ for a snack they would eat later when they were satiated, and satiated subjects underbid 19¢ for a snack they would eat later when they were hungry. Furthermore, we found evidence that these gaps were driven by symmetric mechanisms that operate on the evaluation of visceral features of food, such as taste, as opposed to more cognitive features, such as healthiness.

Keywords
valuation, misprediction, mistakes, empathy gaps, projection bias, symmetry, decision making, preferences

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It is well known that the utility, or value, derived from consumption is modulated by emotional and physiological states at the time of consumption. For example, the pleasure of drinking water is larger when one is thirsty than when one is quenched. A basic question is whether individuals anticipate the effect of these "visceral" states on their utility when making decisions about future consumption. For instance, can a hungry grocery shopper buy the correct amount of food to consume throughout the week? A sizable body of evidence has shown that individuals in a "cold" state (e.g., satiated) systematically underestimate the increase in consumption value that they would experience in a "hot" state (e.g., hungry; Badger et al., 2007; Gilbert, Gill, & Wilson, 2002; Loewenstein, Nagin, & Paternoster, 1997; Nisbett & Kanouse, 1968; Sayette, Loewenstein, Griffin, & Black, 2008; Van Boven & Loewenstein, 2003). This phenomena is known as a *cold-to-hot empathy gap* in psychology (Loewenstein, 1996), and as a *projection bias* in behavioral economics (Loewenstein, O'Donoghue, & Rabin, 2003).

Empathy gaps can arise in two different scenarios. Cold-to-hot gaps refer to situations in which people forecast the value of an event that will occur when they are in a hot state (e.g., eating a hamburger when they are hungry) while they are in a cold state at the time of decision (e.g., after just having eaten). Hot-to-cold gaps refer to the opposite situation (e.g., forecasting the value of eating dessert at the end of the meal in a satiated state while being hungry at the time of decision). An important open question is whether both types of gaps are symmetric in the following two ways. First, do individuals underestimate their change in preferences to the same degree when going from cold-to-hot states as when going from hot-to-cold states? Second, are symmetric mechanisms at work in generating both types of empathy gaps?

The answer to these questions matters for several reasons. First, they inform beliefs about the likelihood that individuals make mistakes of similar magnitude in both types of situations, as well as the extent to which both types of mistakes can be addressed with similar policy

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instruments. Second, theories in behavioral economics and psychology have posited that cold-to-hot and hot-to-cold gaps are symmetric and driven by similar mechanisms, but this has not been previously tested.

Previous work has provided strong evidence for the existence of empathy gaps, but it has not provided a definite answer to either of the two symmetry questions. In fact, the vast majority of experimental studies have focused on the cold-to-hot case (Badger et al., 2007; Gilbert et al., 2002; Loewenstein et al., 1997; Nisbett & Kanouse, 1968; Sayette et al., 2008; Van Boven & Loewenstein, 2003). One important exception is Read and van Leeuwen (1998), who compared hungry-satiated and satiated-hungry empathy gaps in real food choice, as we did in the present experiment. However, unlike our methodology, theirs did not permit a direct comparison of the extent to which changes in utility were underestimated in both cases. With respect to the second question, as far as we know, no previous experiments have investigated the mechanisms at work in projection bias, nor the extent to which they are symmetric.

Method

Subjects

One hundred one students from the California Institute of Technology took part in two behavioral sessions. To encourage subjects to return for the second session, we paid them $10 after the first session and $40 after the second session. The experiment was approved by the California Institute of Technology Institutional Review Board.

Stimuli

Each subject saw two different food sets, each containing 50 different snacks. These snacks consisted of a variety of candies, fruits, chips, and energy bars. Subjects saw one set of foods in the first session and a different set in the second session. The order of the sets was determined randomly for each subject. We used two different sets to avoid consistency biases. During pretesting, all of the foods were rated on average as being neutral or appetitive.

Tasks

The experiment consisted of two sessions that occurred at the same time of day but were separated by 3 to 5 days. Figure 1a summarizes the events in the experiment, and Figure 1b details the timing of a typical trial for each of the tasks. In each session, subjects completed four tasks.

First, subjects performed a liking-rating task in which they rated how much they wanted to eat each of the 50 snacks at the end of that session. Ratings were made on an integer scale from −2 to 2 in response to the question, "How much would you enjoy that particular food at the end of TODAY's experiment?" The purpose of these ratings was to familiarize the subjects with the entire set of foods prior to the main bidding task.

Second, on each day, subjects entered bids for the right to eat each of the foods at the end of the second day of data collection. They were explicitly told whether they would be hungry or satiated at that time. Bids were made in integers from $0 to $4 by pressing a button. At the beginning of the first day, they were informed that at the end of the second session they would need to remain in the lab for 20 min, and the only thing that they would be able to eat was whatever they purchased from us through their bids. At the end of Day 2, one of the foods on which the subject had bid (from either date) was selected, and their bid was implemented using the rules of a Becker-DeGroot-Marschak (BDM) auction (Becker, DeGroot, & Marschak, 1964).[1] Subjects were given $4 in bidding cash and were allowed to keep whatever they did not spend. The bids provided a measure of the perceived value at the time of decision of eating the food at the end of Session 2.

Third, for each of the foods, separate taste and healthiness ratings were made on integer scales from −2 to 2. Subjects provided taste ratings in response to the question "how tasty [do] you believe that food to be, independent of any health considerations." Healthiness ratings were made in response to the question "how healthy [do] you believe that food to be, independent of any taste considerations." The ratings were collected in blocks, with the order randomized across subjects. These ratings provided a measure of the perceived attributes of each food at the time of decision.

Subjects completed the four tasks separately, but the same procedure was followed for each one. Each trial began with a fixation cross (500 ms), after which one of the foods was presented inside a white rectangle. The white rectangle disappeared after 500 ms, and then subjects were free to take as long as they liked to give their rating or place their bid. Response feedback (either the amount of their bid or their rating) appeared on screen for 1 s prior to the start of the next trial.

As shown in Figure 1c, the experiment had a 2 × 2 factorial design, with conditions varying across subjects. For each date, we exogenously manipulated subjects' hunger by asking them either to fast for 4 hr prior to the experiment (hungry condition) or to eat a large snack within half an hour prior to the start of the experiment (satiated condition). This led to four treatment groups: satiated-hungry, satiated-satiated, hungry-satiated, and hungry-hungry. The first dimension denotes whether subjects were hungry or satiated during the first session.

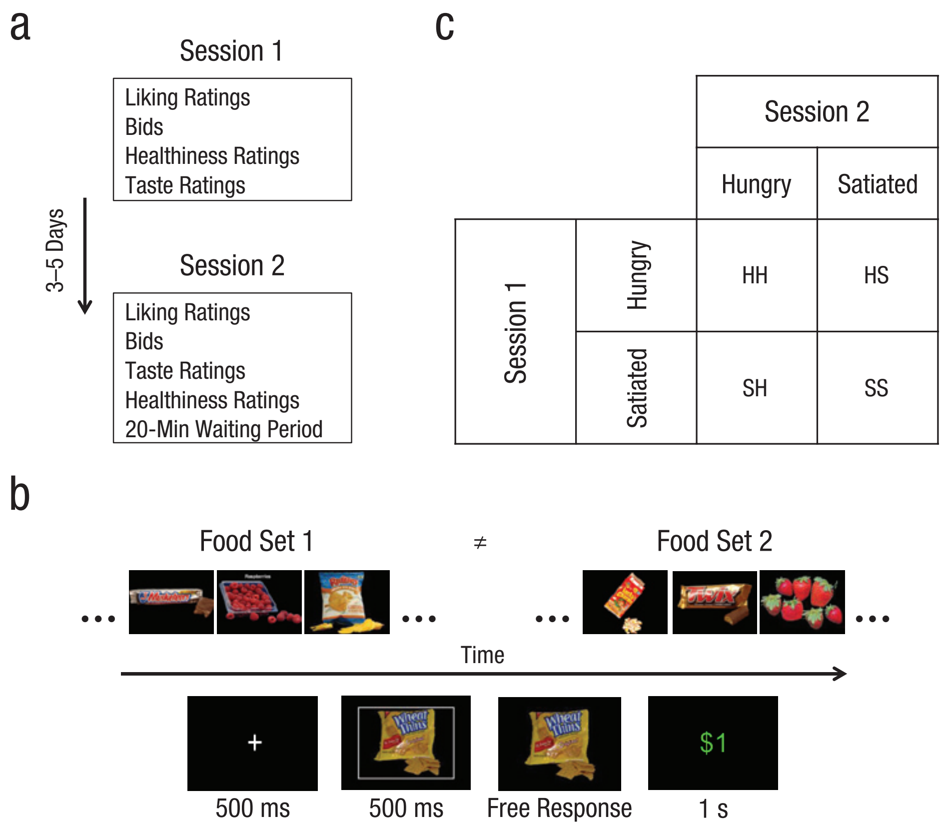

Fig. 1. Procedure and design of the experiment. Subjects took part in two behavioral sessions separated by 3 to 5 days (a). In each session, they made liking, healthiness, and taste ratings for 50 foods. They also placed bids for foods that they could buy and consume at the end of Session 2. Regardless of whether they bought food, subjects were required to remain in the lab for 20 min after the second session. On each day, subjects completed the four tasks with a different set of 50 foods (examples are shown in b), which were presented in a random order across subjects. On each trial for each task, subjects first saw a fixation cross on a computer monitor. Then the trial food was revealed inside a white rectangle. After the rectangle disappeared, subjects had as long as they liked to give their rating or place their bid. Response feedback—either the amount of their bid (shown here) or their rating—was provided at the end of the trial. The experiment consisted of a 2 × 2 design (c), in which subjects were either hungry or satiated at the first session and either hungry or satiated at the second session.

The second dimension denotes whether subjects were hungry or satiated during the second session. There were 23 subjects in the satiated-hungry group, 27 in the satiated-satiated group, 27 in the hungry-satiated group, and 24 in the hungry-hungry group. Before entering the lab, subjects were verbally asked to report the last time they ate. If they gave an answer inconsistent with the instructions, they were excluded from further participation in the experiment (and not reported in the analyses).

Results

Paradigm validation

Figure 2 summarizes the bidding data for all of the conditions. For each day, the bids provide a measure of the perceived value of eating a snack at the end of the second session. The data illustrate several points. First, subjects bid consistently when there were no changes in their state between the two days (Day 1 vs. Day 2 for the hungry-hungry group: $p > .84$; Day 1 vs. Day 2 for the satiated-satiated group: $p > .57$; paired, two-tailed t tests).

Second, the bids on Day 2 did not depend on the subjects' state on Day 1 (Day 2 for the hungry-hungry group vs. Day 2 for the satiated-hungry group: $p > .80$; Day 2 for the satiated-satiated group vs. Day 2 for the hungry-satiated group: $p > .90$; two-tailed t tests). This implies that subjects bid the same amount on Day 2 when they were in the same state, regardless of whether their state at the time of the first bid was the same or different.

In addition, we found no difference between the mean bid on Day 2 for the satiated-hungry group and the

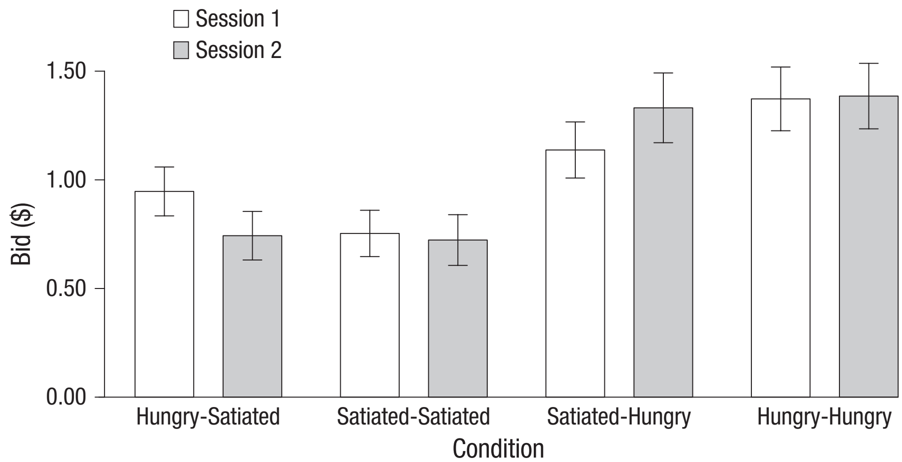

Fig. 2. Mean bid amount as a function of condition and experimental session. Error bars show standard errors.

average bid on Day 1 and Day 2 for the hungry-hungry group ($p > .82$, two-tailed t test) or between the mean bid on Day 2 for the hungry-satiated group and the average bid on Day 1 and Day 2 for the satiated-satiated group ($p > .97$, two-tailed t test). For this reason, in some of the analyses reported hereafter, we pooled the eight bidding conditions into four cases: hungry no-gap (Day 1 hungry-hungry group, Day 2 hungry-hungry group, and Day 2 satiated-hungry group), satiated no-gap (Day 1 satiated-satiated group, Day 2 satiated-satiated group, and Day 2 hungry-satiated group), hungry-satiated gap (Day 1 hungry-satiated group), and satiated-hungry gap (Day 1 satiated-hungry group).[2] We pooled the Day 1 hungry-hungry, Day 2 hungry-hungry, and Day 2 satiated-hungry conditions together and called them the hungry-no-gap case, because in all of those conditions, subjects made decisions in a hungry state about what to consume on Day 2, when they would also be in a hungry state. Analogously, we refer to the Day 1 satiated-satiated, Day 2 satiated-satiated, and Day 2 hungry-satiated conditions as the satiated-no-gap case, because subjects in all of those instances made decisions in a satiated state about consumption on Day 2, when they would also be in a satiated state.

Third, bids in the hungry-no-gap case were on average 62¢ larger than in the satiated-no-gap case ($p < .01$, two-tailed t test), which demonstrates that our state manipulation affected subjects' food values.

Symmetric empathy gap

As shown in Figure 2, we found a cold-to-hot empathy gap: The mean bid on Day 2 for the satiated-hungry group was 19¢ (SE = 8¢) higher than the mean bid on Day 1 for the satiated-hungry group ($p < .018$, two-tailed t test). We also found a hot-to-cold empathy gap: The mean bid on Day 2 for the hungry-satiated group was 20¢ (SE = 8¢) lower than the mean bid on Day 1 for the hungry-satiated group ($p < .016$, two-tailed t test). The value difference was positive in the cold-to-hot case because subjects underestimated the value of eating when hungry when making decisions in a satiated state. The opposite was true in the hot-to-cold case. A direct comparison revealed no differences between the magnitudes of both mistakes, which is consistent with a symmetric effect size for both types of value gaps (|Day 2 for the satiated-hungry group – Day 1 for the satiated-hungry group| vs. |Day 2 hungry-satiated – Day 1 hungry-satiated|; $p > .92$, two-tailed t test).

The next set of results is about the mechanisms at work in the empathy gaps and the extent to which they work symmetrically in the two directions. We hypothesized that the mistakes in value forecasting could operate through three different mechanisms.

First, subjects might change their perception of the attributes of foods, such as how healthy or how tasty they are. For example, they might perceive junk foods to be healthier when making decisions in a hungry state than when making decisions in a satiated state. We refer to this channel as the *attribute-perception mechanism*. We tested for this mechanism by comparing the distribution of taste and healthiness ratings in the different conditions.

Second, hunger might increase the baseline value of all foods, regardless of their attributes. This would show up as a constant shift in the value of the foods. We refer to this channel as the *baseline-value mechanism*. We tested for it by estimating a linear regression, for each subject and session, of the bids on the taste and healthiness ratings, and then comparing the distribution of estimated constants.

Table 1. Mean Taste and Healthiness Ratings in the Four Experimental Cases

Rating	Satiated-no-gap case	Hungry-satiated-gap case	Satiated-hungry-gap case	Hungry-no-gap case
Taste	0.32 (0.36)	0.53 (0.34)	0.37 (0.49)	0.50 (0.45)
Healthiness	–0.53 (0.30)	–0.50 (0.31)	–0.41 (0.39)	–0.42 (0.34)

Note: Standard deviations are given in parentheses. Taste and healthiness ratings were made on integer scales from −2 to 2.

Third, hunger might change how a food's attributes are weighted in computing its value. We refer to this channel as the *attribute-weighting mechanism*. We tested for it using the same linear regression as for the baseline-value mechanism and comparing the distribution of estimated coefficients for the healthiness and taste ratings.

Symmetric attribute-perception mechanism

We tested for the role of the attribute-perception mechanism by comparing the mean taste and healthiness ratings across the four cases: satiated no-gap, hungry-satiated gap, satiated-hungry gap, and hungry no-gap. We pooled the data this way to increase the statistical power of our tests. This approach was justified by the fact that, because there were no significant differences in the bids within each of the four cases, the mechanisms were also likely to be deployed in a similar way within each case. As shown in Table 1, taste ratings were higher in the hungry-satiated-gap case (M = 0.53, SE = 0.07) than in the satiated-no-gap case (M = 0.32, SE = 0.05; p < .02, two-tailed t test). This finding is consistent with the idea that subjects in a hungry state overestimate the degree to which they will perceive the snacks as tasty when satiated. However, we did not find a significant difference between the satiated-hungry-gap case (M = 0.37, SE = 0.10) and the hungry-no-gap case (M = 0.50, SE = 0.07; p < .27, two-tailed t test), although the sign of the difference was in the predicted direction, and the effect size was similar to the previous one. There were also no significant differences between cases for healthiness ratings. Together, these results partially support the hypothesis that the attribution-perception mechanism was at work, and they suggest that hunger affected the perception of the more visceral taste attributes but not the perception of the more cognitive health attributes.

Symmetric baseline-value and attribute-weighting mechanisms

We tested for the role of the baseline-value and attribute-weighting mechanisms by estimating a linear mixed regression model. We regressed the amount bid on an indicator variable for each of the four cases, as well as on an interaction of each indicator with healthiness and taste ratings. Random slopes were fitted for each subject.[3]

The estimates are reported in Table 2. The constants exhibited a pattern similar to that for the bids, underestimating the extent to which their value changes from the state at the time of bid to the state at the time of consumption. In particular, the constant in the hungry-satiated-gap case estimated a baseline value for consumption that was 11¢ higher than that estimated in the satiated-no-gap case, whereas the constant in the satiated-hungry-gap case estimated a baseline value 13¢ lower than that in the hungry-no-gap case. This suggests that the baseline-value effect was symmetric, which we tested by estimating a linear contrast of the distribution of estimated constants (weight: satiated-no-gap case = −1.5, hungry-satiated-gap case = −0.5, satiated-hungry-gap case = 0.5, hungry-no-gap case = 1.5; p < .01).

A comparison of the taste coefficients revealed a similar pattern: A linear test of the taste coefficients suggests that the attribute-weighting mechanism is symmetric for taste (similar weights, p < .01). In contrast, a similar test found no significant differences for the healthiness coefficients (p > .28). Together, these results suggest that both

Table 2. Estimates From a Linear Mixed Regression Model in Which the Bid for Each Food Was Regressed on an Indicator Variable for Each Case and on an Interaction of Each Indicator Variable With Healthiness and Taste Ratings

Predictor	Satiated-no-gap case	Hungry-satiated-gap case	Satiated-hungry-gap case	Hungry-no-gap case
Constant	0.62 (0.07)	0.73 (0.33)	0.93 (0.10)	1.07 (0.08)
Healthiness rating	0.05 (0.02)	0.05 (0.03)	0.11 (0.06)	0.07 (0.03)
Taste rating	0.41 (0.04)	0.49 (0.09)	0.51 (0.06)	0.60 (0.04)

Note: Random slopes were fitted for each subject. Standard errors are given in parentheses.

the baseline value and the attribute mechanism worked in a symmetric fashion. Furthermore, they suggest that the attribute-weighting mechanism changed the valuation of the more visceral taste ratings but not the valuation of the more cognitive healthiness ratings.

Predicting cross-individual differences in empathy gaps

We carried out an additional post hoc analysis to further test the validity of the mechanism results. We reasoned that if the identified mechanisms play a critical role in generating the empathy gaps, they should be correlated with cross-subject differences of the magnitude of the empathy gaps. To test this prediction, we used the data from the hungry-satiated and satiated-hungry conditions to estimate a linear regression of an individual measure of the empathy gaps (given by mean bid in Day 2 minus mean bid in Day 1) on a measure of the individual taste-perception effects (given by mean taste rating in Day 2 minus mean taste rating in Day 1), a measure of the individual baseline-value effects (given by the estimated constant in Day 2 minus the estimated constant in Day 1, for each subject), and the taste-weighting effects (given by the estimated taste coefficient in Day 2 minus the estimated taste coefficient in Day 1, for each subject). The regression took into account the potential of measurement error on the independent variables, because they were estimated from linear regressions at the individual level. As shown in Table 3, we found that the size of the empathy gap was significantly correlated with the size of changes in our three relevant mechanisms. These results provide additional evidence in favor of the mechanism results.

Discussion

In the research reported here, we carried out a modified version of the classic experiment by Read and van Leeuwen (1998) in order to address, first, whether individuals incorrectly predict their change in preferences to the same degree when going from cold-to-hot states as when going from hot-to-cold states and, second, whether symmetric mechanisms are at work in generating both types of empathy gaps.

With respect to the first question, we found that the size of the empathy gap was symmetric: Satiated individuals underestimated the value of foods to consume when hungry by a similar amount that hungry individuals overestimated the value of foods to consume when satiated. This finding supports the types of decision-making models proposed in the projection-bias literature (Conlin, O'Donoghue, & Vogelsang, 2007; Loewenstein et al., 2003). In addition, this result suggests that both types of gaps lead to decision-making mistakes of similar magnitude and thus ought to be of equal importance in public-policy interventions.

With respect to the second question, we found evidence that three different mechanisms are at work in generating empathy gaps, and they appear to operate largely symmetrically. First, we found that subjects perceive the tastiness of food to be greater when making decisions while hungry than while satiated, regardless of their state at the time of consumption (attribute-perception mechanism). Second, we found that they overestimate the value of the average food in hot-to-cold gaps and underestimate it in cold-to-hot gaps (baseline-valuation mechanism). Finally, we found that they overweight the anticipated tastiness of foods in hot-to-cold gaps and underweight it in cold-to-hold gaps (attribute-weighting mechanism).

It is interesting that the attribute-perception and attribute-weighting mechanisms seem to operate in the more visceral taste dimension but not in the more cognitive healthiness dimension. This suggests that changes in visceral states might lead to empathy gaps in part by changing how basic physiological attributes, such as taste, are perceived and weighted but that they do not affect how more abstract attributes, such as healthiness, are represented and weighted. This is important because it suggests that one key to overcoming decision mistakes associated with empathy gaps may be to help individuals

Table 3. Estimates of a Linear Regression of a Measure of the Empathy Gaps on Measures of the Taste-Perception, Baseline-Value, and Taste-Weighting Mechanisms

Predictor	Bid difference (all trials)	Bid difference (satiated-hungry trials only)	Bid difference (hungry-satiated trials only)
Baseline value	0.92** (0.05)	0.92** (0.11)	0.87** (0.05)
Taste perception	0.47** (0.07)	0.65** (0.11)	0.28** (0.08)
Taste weighting	0.39** (0.09)	0.26* (0.12)	0.65** (0.13)

Note: The regression accounted for measurement error on the independent variables. See the text for details. Standard errors are given in parentheses.
*$p < .05$. **$p < .01$.

more accurately forecast these basic variables, instead of attempting to modulate representations of more abstract variables, such as healthiness.

Our findings are also related to the important literature on mistakes in affective forecasting (Gilbert, Pinel, Wilson, Blumberg, & Wheatly, 1998; Gilbert & Wilson, 2007; Riis, Loewenstein, Baron, & Jepson, 2005; Sackett & Torrance, 1978; Sieff, Dawes, & Loewenstein, 1999; Wilson, Wheatley, Meyers, Gilbert, & Axsom, 2000). A key difference between empathy gaps and affective forecasting has to do with the types of values being forecasted and the mechanisms at work. In particular, much of the affective-forecasting literature has focused on predicting the impact of current and future events on future well-being and mood, but not on decision making per se. In addition, a critical mechanism in many affective-forecasting studies is an inability to forecast the speed at which visceral states change (e.g., how long will a person be depressed after a divorce). In contrast, this mechanism is not part of the definition of empathy gaps, in which subjects are assumed to know the future state even if they cannot forecast their future utility properly.

We conclude by emphasizing two limitations of the present experiment. First, the type of empathy gap studied here is likely to be relatively mild compared with those that arise in domains such as addiction (Badger et al., 2007; Sayette et al., 2008) or sexual arousal (Loewenstein et al., 1997). It is conceivable that the symmetry identified here breaks down in those cases, a possibility that should be investigated in future studies. Second, the list of attributes used in this study was far from comprehensive and included only taste and healthiness, which lie in extreme positions of the visceral-cognitive spectrum. It is possible that there are attributes in the middle of the spectrum that also play a role in generating empathy gaps that we have not identified, even in the case of food choices.

Author Contributions

G. Fisher and A. Rangel designed the study, analyzed the data, and wrote the manuscript. G. Fisher programmed the experiment and collected the data.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Notes

1. Briefly, the rules of a BDM auction are as follows. Let b be the bid entered by the subject, and let x be a randomly selected number. If $b \geq x$, the subject gets to eat the snack shown in that trial and only pays \$$x$ for it. If $b < x$, the subject gets nothing and pays nothing. We used this procedure because it is incentive compatible (i.e., the best strategy for the subjects is to bid what they feel is the true value of the items), a fact that was emphasized during the training period.
2. To form the no-gap cases, we first averaged responses within conditions with the same subjects (e.g., average bids on Day 1 and Day 2 for the hungry-hungry group) and then averaged responses from the third group (e.g., Day 2 for the satiated-hungry group).
3. Responses for subjects in the same experimental condition in the no-gap cases were equally weighted because subjects saw different foods on each day.

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