Pictures of Food Have Reward Value that Varies According to Appetitive State

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3188 words

RUNNING HEAD: Reward value of food pictures

Abstract

A stimulus is considered a reward if an animal will perform work in order to receive it. In this study we asked whether pictures of food can be rewards for human subjects, with reward value operationalized as the physical effort the subjects would exert to continue viewing the pictures. We designed a procedure, modeled on the animal literature of operant conditioning, under which subjects viewed two sets of pictures of appetizing and unappetizing food items, and controlled how long each picture remained in view by repeatedly pressing pairs of keys on a computer. Subjects performed this procedure twice, once while hungry and once after consuming a meal. We found that in general, appetizing food pictures were viewed longer than unappetizing food pictures. When subjects were hungry (in a deficit state specific to food reward), this difference in favor of appetizing food pictures was even greater than when subjects were satiated. These results show that pictures of food items do indeed have reward value in the absence of the food items themselves, and more generally, that pictures of rewards can stand in for actual rewards.

Introduction

Reward is a concept that refers to the positive value an animal attributes to an object, an event, or an internal state. Rewards are defined operationally by the effort an animal will expend to consume or get closer to them. As an incentive to behavior, a rewarding stimulus acts either via a memory of a previous reward experience or via salient properties of the stimulus (i.e., the sight and smell of food) which orient the animal to it. As a reinforcement of previous behavior, a rewarding stimulus acts to increase the probability that preceding behavioral responses are repeated; such positive reinforcers increase the frequency of behavioral reactions during learning and maintain these behaviors after learning (Schultz, Dayan, & Montague, 1997). The processing of reward information is a fundamental component of the cognitive and neural substrates of normal behavior, and its malfunction has been suggested in a number of mental disorders (Breiter et al., 1996; Breiter & Rosen, 1999), including abnormal eating behavior (Schachter, 1968, 1971).

The reward value associated with a stimulus is not a static, intrinsic property, but is rather a function of the animal's internal state at the time and of its past experience with the stimulus. Primary homeostatic functions lead to drives such as eating, drinking, and thermal regulation on the basis of deficit states, or changes in physiological conditions. Deficit states increase the reward value of stimuli that have the potential to reduce that deficit. For example, the reward value of food increases during hunger (Cabanac, 1971).

To the brain, all rewards are initially perceived and transcribed as distributed sets of signals in primary sensory cortices. Only subsequently are these representations processed into discrete information dimensions that can be useful for planning behavior. The initial perceptual representations in the brain may be thought of as lying on a continuum between an abstract code (e.g., the word "cheeseburger") and the encoding of internal physiological signals (e.g., the increase in plasma glucose levels, hormone fluctuations, and other physiological events associated with the consumption and digestion of a cheeseburger). Between these extremes lie other inputs such as visual, olfactory, and taste representations of food.

Although it is well-known that the consumption, taste, or smell of food can have rewarding effects (as reviewed by Rolls, 1999), it is not clear that viewing pictures of food items will be reinforcing in the absence of the actual food items. Pictures of food may be too close to the abstract end of the continuum to have a reinforcing effect. The same question can be asked of many reward categories, and the answer has important consequences for our understanding of reward representations. Food, however, is an especially apt category for study because the deficit state of hunger can readily be induced (and relieved) in a short-term experiment, and pictures of food are near-veridical representations of the underlying rewards. Furthermore, there is evidence that neural pathways that animals and humans will work to activate (via electrical self-stimulation) can also be activated in monkeys by the sight of food (Rolls, 1999).

In this study, we asked two questions: (1) Can pictures of homeostatic rewards, in this case food items, function as rewards by causing human subjects to work in order to continue viewing them? (2) Does this valuation of food pictures vary depending on the subjects' physiological state, such as hunger or satiety? We used a "keypress" procedure adapted from bar-pressing paradigms in the operant conditioning literature to operationalize reward value as the amount of work subjects would perform to continue viewing pictures of food items. Methods that quantify work to measure reward value have advantages over methods traditionally used in cognitive and social psychology, such as rating scales and monetary valuations (Ariely & Loewenstein, 2000). In particular, our keypress procedure measures an objective, continuous parameter of physical behavior rather than a subjective judgement expressed in arbitrary codes or units. We expected that subjects would generally work harder to view pictures of appetizing food than pictures of non-appetizing food, and that the deficit state of hunger would magnify this effect. Such a finding would imply that pictures of food can indeed serve as rewards.

Method

Participants

Fourteen male subjects (ages 22–40, mean 27.8, SD 6.1) participated as paid volunteers. All were right-handed, non-vegetarian, and free of psychiatric problems (including eating disorders), neurological disease, and illicit substance dependence. None reported engaging in dietary restraint in order to lose weight, or smoking more than one pack of cigarettes per day. Subjects had body-mass indices[1] between 20.6 and 29.3 (mean 24.8, SD 2.1). To verify that subjects exhibited normal eating behavior, we administered the Three Factor Eating Questionnaire (Stunkard & Messick, 1985), which measures three dimensions of human eating behavior: cognitive restraint, disinhibition, and perceived hunger. Subjects' mean scores (Restraint, mean 6.5, SD 4.6; Disinhibition, mean 5.9, SD 3.3; Hunger, mean 5.4, SD 3.1) were within the published normal ranges. All subjects gave written informed consent, and their rights were protected.

Materials

We used 222 photograph-quality digital pictures of food, which were approximately 250 pixels wide and high (on average), corresponding to an area of approximately 10 degrees of

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1. Body Mass Index (BMI) is the most frequently used formula for estimating body fat stores. BMI is the ratio between an individual's weight and the square of his/her height (kg/m^2). The normal range of BMI for adults is 18–25 kg/m^2. Overweight is defined as a BMI between 25 and 30, and obesity is defined as a BMI greater than 30 (World Health Organization Expert Committee, 1995).

visual angle on each side when viewed at a distance of 50 cm. The pictures were selected to fall into four different categories: (1) “Normal,” or normally-colored food items, (2) “Discolored,” or discolored food items, (3) “Prepared,” or prepared food items, and (4) “Unprepared,” or unprepared food ingredients. (See **Figure 1** for examples of each category.) The Normal category contained 68 different pictures of food, retrieved from sources on the Internet. The Discolored category contained the same 68 pictures, but with their colors altered so as to no longer appear natural: Using PhotoShop 5.5 software (Adobe Systems) on an iMac DV computer (Apple Computer) we shifted the hue for reds by +75 and the hue for yellows by –110. The Prepared and Unprepared food categories each consisted of 43 different pictures retrieved from the same sources. These pictures were matched between groups (for example, a picture of a cooked steak was matched with a picture of a raw steak).

The following additional written instruments were used: (1) a pre-session state questionnaire, which requested subjective ratings, on a 100-mm visual analogue scale, of 13 physiological or psychological conditions: sluggish, full/satiated, emotionally agitated, alert, anxious, thirsty, happy, desire to eat, energetic, emotionally calm, hungry, sad, and tired; (2) a similar post-session state questionnaire; (3) a post-study questionnaire, which asked about subject performance during the study.

Procedure

Each subject participated in two experimental sessions separated by 3–10 days, one in a “Hungry” state and the other in a “Satiated” state. The order was counterbalanced so that half of the subjects were in the Hungry state before the Satiated state, and vice-versa for the other half of the subjects. Although all subjects participated in both conditions, they were told in advance that their condition would be selected at random for each session, and that their condition for the second session would be independent of their condition during the first session.

Each subject came to each session between 11:00 AM and 1:00 PM, having been instructed to not eat after 12:00 midnight the night before, and not at all on that day. Subjects were allowed to drink water, as well as any caffeinated beverages they would normally drink, but no other fluids. Subjects were told that they would receive a meal as part of each session. Subjects filled out the Three Factor Eating Questionnaire before their first session, and the pre-session questionnaire at the beginning of each session. Subjects in the Hungry condition filled out the pre-session questionnaire, completed the experimental task, and were then given a meal of their choice from the hospital cafeteria; subjects in the Satiated condition were first given the meal, then filled out the pre-session questionnaire and finally completed the experiment. Seven of the 14 subjects completed the post-session questionnaire at the end of each session, and the post-study questionnaire at the end of their second session.

During the experimental task, which was identical in each session, subjects viewed pictures of food on an iMac DV computer for a fixed period of 40 minutes. The 222-picture set cycled until the 40 minutes had elapsed. The pictures were presented in a newly-generated random order for each subject and cycle. Subjects controlled how long they viewed each picture. Without intervention, each picture remained on the screen for 6 seconds. By alternately pressing the Z and X keys on the computer keyboard, subjects could increase the duration, to a maximum of 12 seconds; by alternately pressing the N and M keys, subjects could decrease the duration, to a theoretical minimum of 0 seconds (see **Figure 2**).[2] This procedure was controlled by

2. Under this procedure, each pair of keypresses increased or decreased the total viewing time according to the following formula: NewTotalTime = OldTotalTime + (ExtremeTime–OldTotalTime) / K, where ExtremeTime was 0 seconds for keypresses intended to reduce the viewing time, ExtremeTime was 12 seconds for keypresses intended to increase the viewing time, and K was a scaling constant set to 40. If at any time the elapsed viewing time for the picture surpassed the total time determined by the subject's keypressing behavior, the picture was removed and the next trial began. Note that this formula has the effect of making successive keypresses of the same sort less and less

customized software developed with Authorware (Macromedia), which also recorded how long each picture remained on the screen (for further details, see Ariely, Breiter, & Aharon, 2001).

Results

Since subjects had to perform physical work to alter the viewing times for a picture from the 6-second default, the viewing time measure operationalizes our concept of the reward value (positive or negative) of a stimulus. We conducted separate repeated-measures analyses of variance for the Normal–Discolored and Prepared–Unprepared comparisons. In each case the within-subjects variables were State (Hungry vs. Satiated) and Picture Type (Normal vs. Discolored, or Prepared vs. Unprepared), with Condition Order (Hungry first vs. Satiated first) as a between-subjects variable.

Normal vs. Discolored. There was a significant main effect of Picture Type, with subjects viewing the Normal pictures longer than the Discolored pictures (6.87 vs. 5.00 sec), $F(1,12)=21.06$, $p=.0006$, $r=.80$ (**Figure 3**). There was also a significant main effect of State, with subjects viewing both the Normal and Discolored pictures longer when hungry than when satiated (6.43 vs. 5.44 sec), $F(1,12)=14.97$, $p=.0022$, $r=.75$. An interaction between Picture Type and State was observed, with the effect of Picture Type being larger when subjects were hungry than when they were satiated, $F(1,12)=20.98$, $p=.0006$, $r=.80$ (**Figure 4**).

There was a significant main effect of Condition Order, with subjects viewing both Normal and Discolored pictures longer across both sessions when they were satiated during their first session than when they were hungry during their first session (6.5 vs. 5.4 secs), $F(1,12)=14.55$, $p=.0025$, $r=.74$. However, there were no significant interactions involving the

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effective in modifying the total viewing time. A "slider" was displayed to the left of each picture to indicate the total viewing time determined by the subject's keypresses for that picture (Ariely, Breiter, & Aharon, 2001).

Condition Order variable. To rule out the possibility that the results were an artifact of differences in Condition Order, we analyzed separately the first condition that each subject participated in. In this analysis, State was a between-subjects variable and there was no Condition Order variable. The greater reward valuation of Normal over Discolored pictures, as well as the enhancement of this effect during Hunger over Satiety, persisted in this analysis, indicating that the results were not an artifact of subjects' having experience with both states.

Each of the 222 pictures was viewed 1–3 times by each subject over the 40 minute experiment. In the hungry state, subjects viewed an average of 369 pictures, and cycled through the complete set an average of 1.66 times. In the satiated state, subjects viewed an average of 437 pictures, and cycled through the complete set an average of 1.97 times. Because each picture was viewed a different number of times by each subject, and repeated viewing of the same picture might result in habituation, we repeated our analyses using only the data from the first time each picture was viewed. The pattern of results was the same.

Prepared vs. Unprepared. These results followed the pattern of the Normal and Discolored pictures, but the effects were somewhat smaller. There was a significant main effect of Picture Type, with subjects viewing the Prepared pictures longer than the Unprepared pictures (6.92 vs. 6.02 s), $F(1,12)=13.54$, $p=.0032$, $r=.73$ (Figure 3). There was also a significant main effect of State, with subjects viewing both the Prepared and Unprepared pictures longer when hungry than when satiated (6.99 vs. 5.95 secs), $F(1,12)=11.05$, $p=.0061$, $r=.69$. An interaction between Picture Type and State was observed, with the effect of Picture Type being larger when subjects were hungry than when they were satiated, $F(1,12)=10.44$, $p=.0072$, $r=.68$ (Figure 4). There was a significant main effect of order, with subjects viewing both Prepared and Unprepared pictures longer when satiated during their first session than when hungry during their first session (7.16 vs. 5.79 secs), $F(1,12)=10.26$, $p=.0076$, $r=.68$. There were no significant interactions involving the Condition Order variable. Again, to control for order effects, we analyzed the first condition separately, and found the same pattern of results. Finally, we analyzed the data from the first exposure to each picture, and again found the same pattern.

Pre- and post-experiment assessments. We confirmed that our manipulation of appetitive state had the desired effect by examining the pre- and post-session state questionnaires. All 14 subjects completed the pre-session questionnaire, once when hungry and once when satiated. There were significant differences in the expected direction between the two conditions for seven of the states: hungry, desire to eat, full/satiated, thirsty, calm, agitated, and happy ($p < .05$ in each case). Seven of the 14 subjects also completed the post-session questionnaire. In the Hungry condition, there were significant changes from the beginning of the experiment to the end of the experiment in two of the states: tired and anxious (both greater at the end, $p < .05$ in each case). In the Satiated condition, there were no significant changes in any of the states from the beginning to the end of the experiment.

Discussion

As predicted, subjects expended physical effort to view pictures of appetizing food longer than matched pictures of non-appetizing discolored food or food ingredients, and this effect was larger when subjects were in an experimentally induced state of hunger than when they were satiated from recently consuming a meal. The same pattern of results occurred when only the first of those states experienced by each subject was considered (so that memory of the previous state or knowledge of the complete experimental design could not affect behavior). To our knowledge, this is the first study to show that visual images of food can act as reinforcements of effortful behavior (i.e., serve as rewarding stimuli). The fact that inducing a physiological deficit state increased the effect adds indirect support for these conclusions by locating the pictures of food along the specific reward continuum related to appetitive state.

The effects of hunger state also argue against interpreting our results as caused entirely by the demand characteristics of the experimental situation. While the general concept of "food" was made salient by many aspects of the procedure, both the written instructions and the experimenter herself carefully avoided any disclosure of the study's design or purpose, and no subject correctly guessed the study's hypothesis. Furthermore, in an analogous study that used the same keypress procedure to compare viewing times for beautiful and average-looking male and female faces (Aharon et al., 2001), heterosexual male subjects worked to increase the viewing time of beautiful female faces, relative to the other three categories, despite *not* being directed in any way to attend to beautiful or female faces, either explicitly or implicitly, by the experimental method. Thus, the validity of our keypress procedure as an operationalization of reward value is neither peculiar to food nor a mere side effect of the experimental demands placed upon subjects.

It is interesting to note that the difference between the "appetizing" and "non-appetizing" categories of pictures was somewhat greater for the Normal–Discolored comparison than for the Prepared–Unprepared comparison. Although this might have been caused by the greater number of pictures in the former than the latter comparison, the more precise matching of appetizing and unappetizing pictures in that comparison, or the presence in the Unprepared category of some food items that are already edible without preparation (e.g., vegetables), the most intriguing possibility is that our discoloration procedure shifted the predominant colors of the original food images to hues that occur very rarely in food that is actually consumed, and may even serve as direct signals of unappetizing food. Support for this interpretation comes from research showing that rhesus monkeys pay more attention to the color of food items than to their shapes (Santos, Hauser, & Spelke, 2001). However, it is important to note that the difference in color values between the two categories cannot explain away the reward valuation effect we observed, because (1) we observed a similar effect with the Prepared–Unprepared comparison, in which the categories were much closer in color values, and no "unnatural" colors were included, and (2) we observed an interaction with appetitive state in each case, for which there is no parsimonious color-based explanation.

When food appears unappetizing or unnatural, we have important information that may prevent us from consuming it. Previous research has shown that representations of ingestable items that are clearly known to be artificial can nevertheless evoke negative emotions and behaviors. For example, subjects given the choice would rather place a rubber sink mat between their lips than a piece of new, fake rubber vomit (Rozin, Millman, & Nemeroff, 1986). The top-down knowledge that the vomit was not real was not sufficient to override the automatic disgust reaction to the depiction of vomit. However, automatic signals are not always by themselves sufficient to control ingestive behavior: amnesic patients who have already consumed a full meal will consume another one if it is offered (Rozin, Dow, Moscovitch, & Rajaram, 1998). In this case, explicit memory of recent eating experiences appears necessary to confirm the physiological state of satiety, and without such memory, the state can be overridden. Taken together, these findings suggest that explicit and implicit representations of physiological state and external stimuli interact to produce ingestive behavior.

Our results suggest that visual representations of food can have reward value by an objective measure, namely work performed to increase or decrease the time an image is perceived. As with brain stimulation reward (Olds & Milner, 1954; Shizgal, 1999), these representations do not themselves have any effect on the hedonic deficit state, but they do have their own reinforcing effects. Traditionally, stimuli which act to orient an animal via a memory of a previous reward experience, or via salient properties (i.e., the sight or smell of food) of the stimuli, are considered to be *incentive* rewards. Our results suggest that such representations may also act as *reinforcing* rewards; however, their values are still influenced by the physiological deficit state (i.e., hunger) of the experimental subjects. We have recently used the procedure described here to show that a completely different category of visual stimuli, namely pictures of attractive faces, can also have reward value, and that the reward value of such stimuli dissociates from their aesthetic value as measured by rating scales (Aharon et al., 2001), illustrating the important distinction between “liking” and “wanting” in the study of human emotion and motivation (see Berridge, 1996, 2000). Accordingly, our keypress method has the potential to simplify and thus facilitate neuroimaging of reward circuitry activated in response to different stimuli in humans under a variety of experimentally-induced states or medical or psychiatric disorders.

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Author Note

We thank Tod Gulick for valuable advice.

This work was supported by grants to (1) the MGH NMR Center for the post-doctoral fellowship supporting Dr. Chabris, (2) Dr. Kaplan from the National Institutes of Health (RO1 DK57478), Bethesda, MD, and (3) Dr. Breiter from the National Institutes of Health (PO1 DA09467 & K21 DA00265), Bethesda, MD. Dr. Breiter was further supported by the Office of National Drug Control Policy (ONDCP). Drs. Aharon and Breiter, along with Ms. Huffman, were further supported by the National Center for Responsible Gaming (NCRG).

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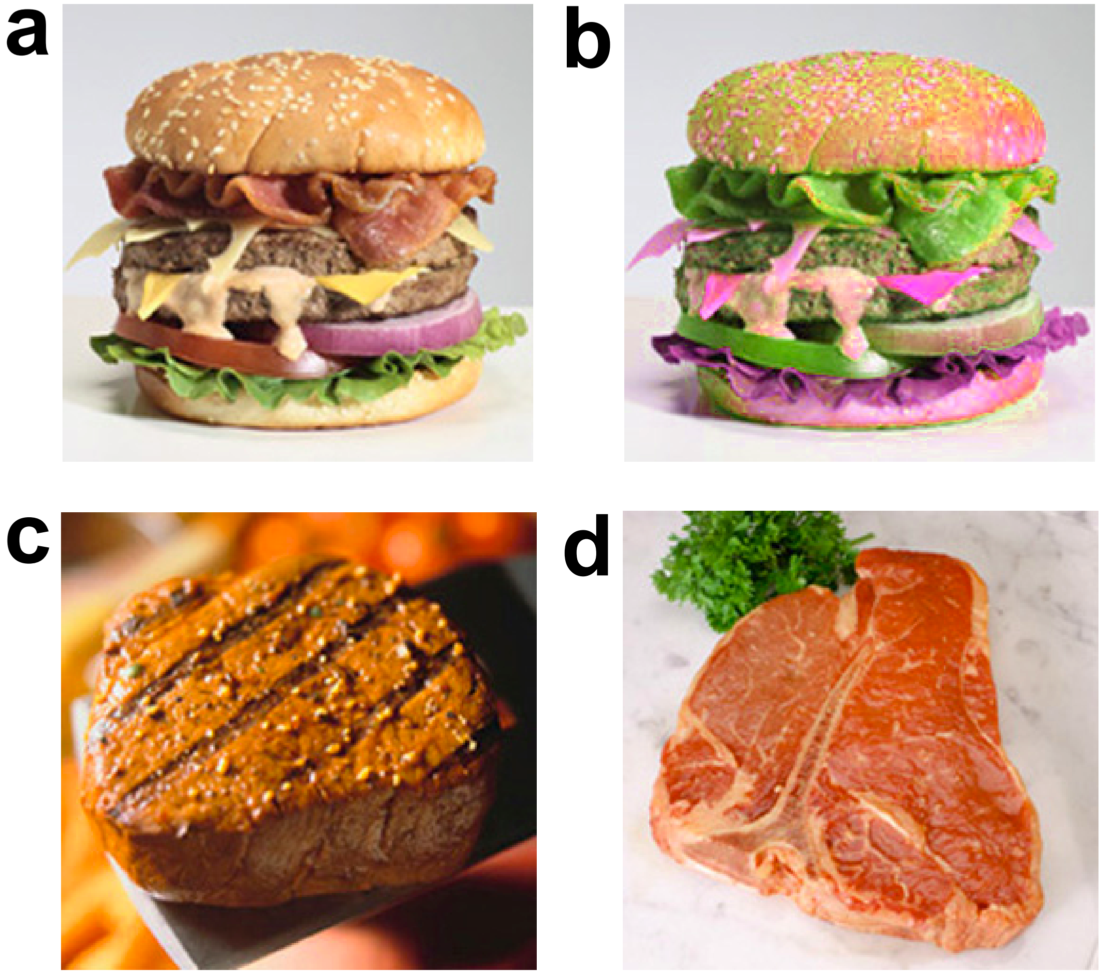

Figure 1. One example of each stimulus category: (a) Normally colored food item; (b) Discolored food item; (c) Prepared food item; (d) Unprepared food item.

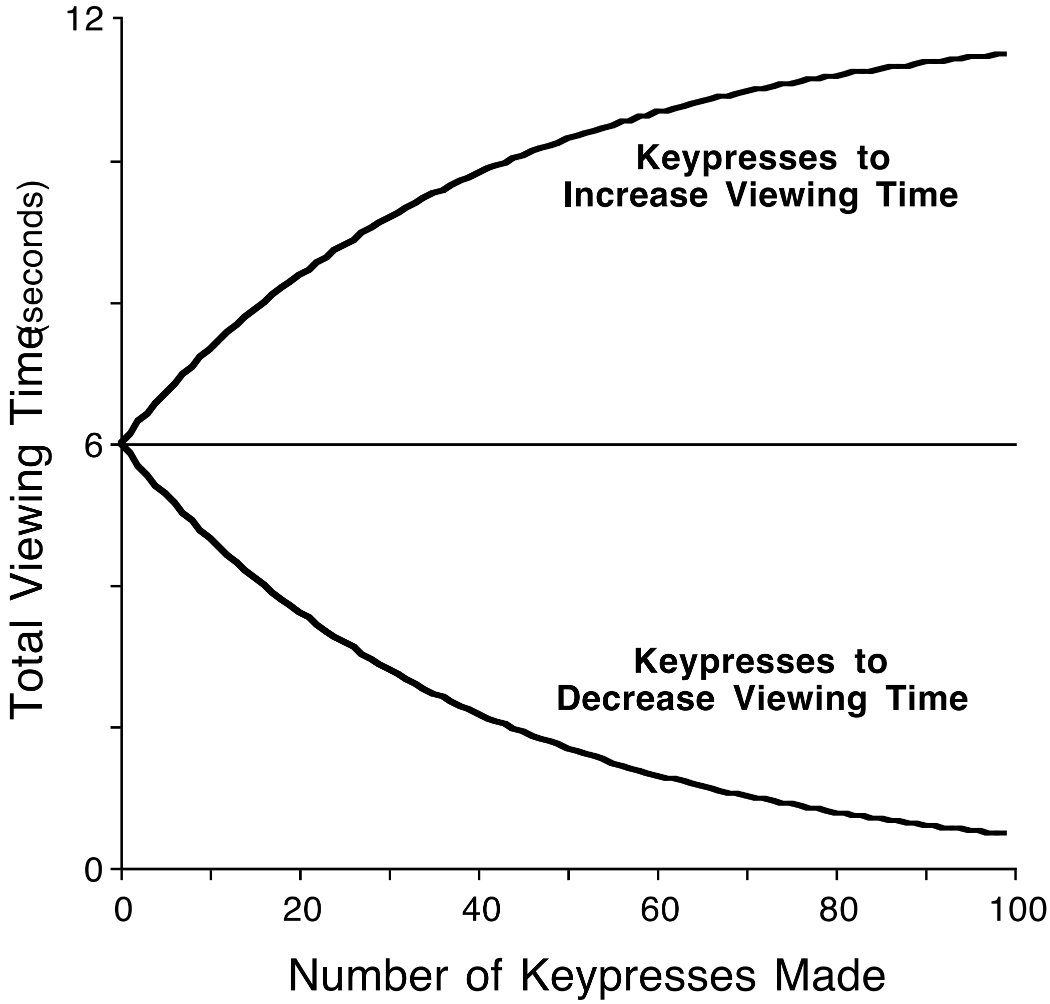

Figure 2. Effect of repeatedly pressing the same pair of keys on the total viewing time for the picture currently being presented. Note that each additional keypress of a given type had a smaller effect than the previous one, and that the total viewing time of a picture was a function solely of the sequence of keypresses the subject made while viewing that picture.

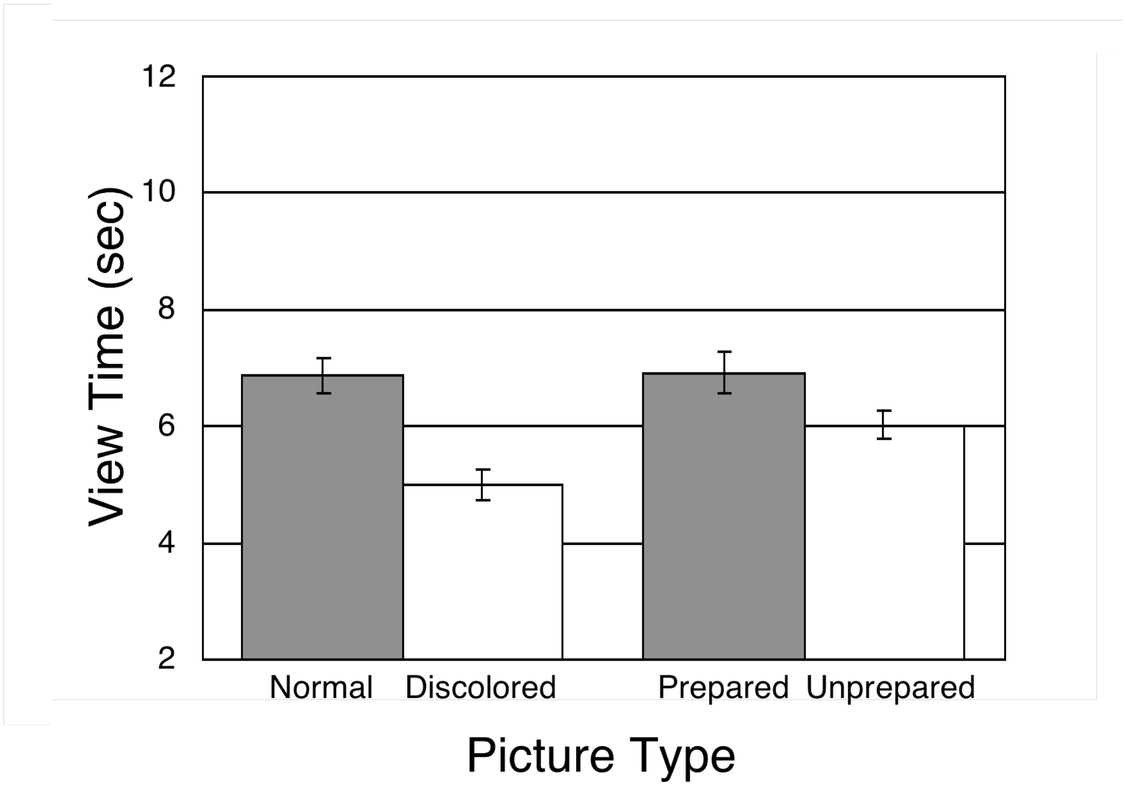

Figure 3. Viewing time of food pictures as a function of category. Results are displayed as means and standard errors. Normal food items were viewed longer than Discolored food items, and Prepared food items were viewed longer than Unprepared food items.

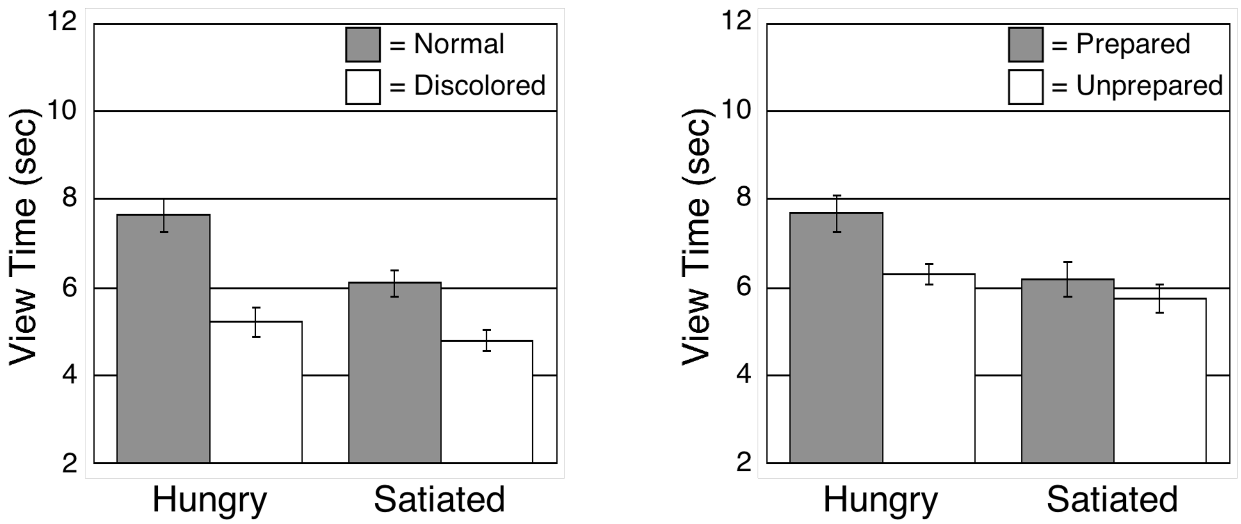

Figure 4. Viewing time of food pictures as a function of category and appetitive state: *Left:* Normal versus Discolored food items. *Right:* Prepared versus Unprepared food items. Results are displayed as means and standard errors. The increase in viewing time for Normal and Prepared food items over Discolored and Unprepared food items was larger in the Hungry state than in the Satiated state.