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A bait we cannot avoid: Food-induced motor distractibility

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ABSTRACT

Food is so central to humans' life that keeping our mind away from it is not an easy task. Because of its strong motivational value, food cues attract our attention. However, often food is truly not relevant to our on-going activities. In the present study we investigated the distracting role that task-irrelevant foods (natural and manufactured) and food-cues play in performing goal-directed reaching movements. We explored whether spatial and temporal parameters of reaching movement were influenced by the presence of task-irrelevant stimuli (i.e., distractor effect), and whether this effect was modulated by participants' implicit and explicit ratings of food items and participants' tendency to restrain their diet. First we found that the movement trajectory veered consistently toward food items and food-related distractors. Second, we found that participants' own evaluation of natural and manufactured food played a differential predicting role of the magnitude of temporal and spatial parameters of the distractor effect induced by these types of food. We conclude that perceptual and attentional systems provide preferential access to stimuli in the environment with high significance for organisms.

1. Introduction

Food is essential for our survival. For this reason our brain is likely to be endowed with the ability to readily recognize edible items in the environment. What are the consequences of the presence of food for our behavior and action? Imagine a sunny afternoon while you are walking down a downtown street to go meeting some friends. You pass by an ice-cream stand. You are not hungry and you have no intention to buy any food, nevertheless, your attention is driven toward this food cue presented in the environment. In order to maintain your focus and reach your goal in such situation, your perceptual and attentional systems need to be able to ignore this irrelevant alluring information. Will you be able to ignore such distractions and reach 'safely' your destination? The answer is generally 'YES' but we are also aware that it is not always an easy task and that we often fail indulging in the allure of temptation (Jeffery et al., 2000) and our actions may be influenced so that you might find yourself moving toward the ice-cream stand.

Food cues are hard to resist because of their strong motivational value (Ouwehand & Papies, 2010). In fact, their simple presence leads people to direct selectively their attention toward attractive food items (Papies, Stroebe, & Aarts, 2008a). Results indicate that people have strong drives (i.e., 'wanting') and are willing to expend quite some effort to obtain food, in particular, when calories content is high (e.g., Goldfield & Epstein, 2002). Perceiving rewarding food does even more, such as triggering motor impulses to obtain and eat them that in turn facilitate consumption (Papies et al., 2008a; Veling & Aarts, 2011). Nowadays, the mass production and distribution together with the culinary developments have produced a 'toxic environment' where there is an excessive availability of food that is considered partially responsible for the increased intake of high-calories, palatable food (Hill & Peters, 1998; Wadden, Brownell, & Foster, 2002) and, in turn, for the raise in overeating and the prevalence of overweight and obesity (Ouwehand & Papies, 2010).

There are a few studies that examined approach tendencies toward food usually focusing on their potential role in overeating and deregulation of food intake (see Veenstra & de Jong, 2010). Food is all around us and often is not relevant to our primary goal, and in some cases it might even play a 'distracting role' and influence our on-going actions. Many of our behaviors and actions, in fact, are influenced by the presence of 'distracting' stimuli in our environment to which we often react automatically without much conscious deliberation (e.g., Ambron & Foroni, 2015; Moher & Song, 2013; Strack & Deutsch, 2004). This seems especially true for food stimuli due to their relevance for our survival.

The present research investigates the distracting impact of food on motor actions for the first time focusing on how food items when presented as task-irrelevant stimuli (i.e., distractors) may

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interference with ongoing goal-directed actions (i.e., reaching movements toward a target). By focusing on reaching movements we can investigate automatic default motor mechanisms that are ubiquitous in our daily life (cf. Milner, 1996) while systematically manipulating the characteristic of the stimuli (e.g., different types of food) and controlling for possible moderating variables. The information gained by this approach provides valuable insights that go beyond button pressing and reaction times that are considered a measure of processing and movement planning (Rosenbaum, 1985). In addition, this approach provides more detailed information regarding the characteristics and the nature of such effect by exploring both temporal and spatial parameters of the action and as such paralleling more complex behaviors and attitudes toward food in real life context.

1.1. Distractor effect in motor action

When reaching for an object, the presence in the close environment of an attention-grabbing visual stimulus (i.e., distractor), may influence our movement even if this stimulus is not the target of our action. This phenomenon is known as 'distractor effect' (Howard & Tipper, 1997; Welsh & Elliott, 2004) and refers to changes in spatial (i.e., movement trajectory) and/or temporal (e.g., movement time, reaction times, etc.) aspects of our movement. These changes induced by the presence of a distractor suggest that a motor response is planned not only toward the target but also toward this irrelevant stimulus. The reaching movement is the result of specific attentional mechanisms that select the motor program needed to accurately act upon a target and simultaneously maintain at a lower threshold (i.e., inhibit) the motor programs for irrelevant distractors (Allport, 1987). If, from one hand, changes in temporal and spatial parameters of the action suggest that the presence of the distractor elicits a response that competes with the response toward the target, on the other hand, the successful completion of the reaching movement demonstrates that the response toward the distractor is afterwards inhibited to complete the intended reaching of the target (Howard & Tipper, 1997; Welsh & Elliott, 2004). In this sense, the outcome of the action and the movement trajectory will depend upon the degree of activation and subsequent inhibition of the response elicited by the distractor, which may deviate from the 'ideal' reaching path by veering toward (or away from) the distractor location. The final movement trajectory is also influenced by (i) the characteristics of the stimuli, as task salient distractors are more difficult to suppress, and by (ii) subject's ability to inhibit the response toward the distractor (Tipper, Howard, & Houghton, 1998).

Young healthy adults seem to be able to inhibit the tendency to veer toward a distractor particularly when task-irrelevant (Ambron, Della Sala, & McIntosh, 2012; Welsh & Elliott, 2005). Recent investigations, however, demonstrated that also young healthy adults might be victim of the distracting role of task-irrelevant stimuli if salient for the subject (i.e., emotional expressions of co-species; Ambron & Foroni, 2015). Due to the importance of food for our survival, it is plausible that food, even when irrelevant to the current goal-oriented action, may still capture our attention and impact our actions.

Previous research (e.g., Castiello, 1996; Jervis, Bennett, Thomas, & Castiello, 1999) investigated the possible passive processing of food distractors implementing a kinematic analysis of upper limb reach-to-grasp movements to a target fruit. Based on results from multiple experiments it was concluded that irrelevant stimuli not physically immediate, or of no immediate behavioral importance, are ignored and do not produce interference. Namely, temporal aspects of the movement and grip magnitude were not affected in such situations. In general, interference effects seem to occur when covert attention is oriented to the distractor (for a review see Castiello, 1999). The reach-to-grasp paradigm implemented by Castiello (1996), however, greatly differs from the present paradigm (but see experiment 2D in Castiello, 1996). Additionally, no spatial parameters of the trajectory related to the distractor-effect were collected leaving untested whether food and food-related items can be so salient to affect movement trajectories during reaching task. The investigation on the 'distracting' effect of food calls also for a better understanding of the potential moderating role of the characteristics of the distractor (i.e., food) and of the to-be-distracted actors. We will discuss them now in turn.

1.2. Food characteristics

Nowadays, most of the food that we are exposed to and we choose from underwent some forms of transformation (e.g., cooking, preservation, preparation and aggregation). The distinction between natural food (Nf) and manufactured food (Mf) is particularly important and unexplored so far (but see Foroni, Pergola, Argiris, & Rumiati, 2013; Rumiati & Foroni, 2015; Rumiati, Foroni, Pergola, Rossi, & Silveri, in press). This distinction is considered vital in the evolution of our species because cooking is considered an important component in the evolutionary jump to Homo erectus. Cooking, in fact, has been argued to have improved our ancestors' diet by increasing the energy gain and, in turn, the brain volume and its capacities (see Wrangham, 2009).

The second and, possibly, most investigated characteristic of food is calorie content (e.g., Frank, Laharnar, et al., 2010; Kadohisa, Verhagen, et al., 2005; Killgore, Young, et al., 2003; LaBar, Gitelman, et al., 2001; Nummenmaa et al., 2012; Simmons, Martin, et al., 2005). Energy value and palatability are in fact critical in eating choice and behavior. Brain imaging studies implementing fMRI and EEG techniques demonstrated how the human brain differentiates high calorie-content food from low calorie-content food (e.g., Killgore et al., 2003; Tang, Fellows, & Dagher, 2014; Toepel, Knebel, Hudry, le Coutre, & Murray, 2009). These studies together suggest that the food's energetic content is a reward property that is processed very rapidly by a distributed network of brain regions typically involving object categorization (occipital regions and temporo-parietal cortices), reward assessment (prefrontal cortex), evaluation of the biological relevance of a stimulus (medial and dorsolateral prefrontal cortex and the diencephalon), and decision making (inferior frontal cortices). At the behavioral level, the distinction between high-calorie palatable food and low-calorie healthier food has been investigated focusing on the social cognitive processes involved in resisting impulsive behaviors and overeating of palatable food (for a review see Hofmann, Friese, & Wiers, 2008; Papies, Stroebe, & Aarts, 2008b). These studies have often investigated special populations mostly focusing on female-only participants or on chronic dieters (i.e., retrained eaters), as these groups tend to show systematic differences in their cognitive processes and reactions to food stimuli compared to the rest of the population (Stroebe, Van Koningsbruggen, Papies, & Aarts, 2013).

These considerations highlight the need to extend the exploration of food processing to a more representative sample in which important variables (e.g., restrain eating level) are also assessed. Restrained eaters, in fact, show increased attentional biases toward food-related stimuli during cognitive tasks (Watson & Garvey, 2013) and thus, the level of diet restrain is a potential moderating variable for the present purposes. In addition, as attitude toward food, desire to eat (i.e., wanting), and healthy features of food play a role during perception of food stimuli, it would also be important to combine these assessments during the exploration of the distracting role of food in motor actions. Food preference, for instance, systematically influences approach/avoidance tendencies as measure by participants' tendency of sway toward or away a highly preferred versus unpreferred food (Brunyé et al., 2013). The interest in such approach/avoidance tendencies lays in the fact that approach/avoidance motor actions have important implications in eating behavior and they even influence food intake (Förster, 2003).

An additional distinction, relevant for the present study, is the one between attitudes toward food considered 'explicit' (i.e., consciously reported by the participants) and those instead considered 'implicit' (i.e., assessed indirectly and not consciously accessible to participants: see Foroni & Bel-Bahar, 2010; Foroni & Semin, 2012). Explicit and implicit attitudes have, in fact, differential predictive validity and they seem to interactively determine our behavior and choice in different contexts and situations (Perugini, 2005; but see also Roefs & Jansen, 2002).

1.3. Overview of the study

The present study investigates how the presence of food and food-related cues irrelevant to our main goal can influence our actions implementing a reaching task. As previous literature has shown, food items represent important attentional cues, are able to attract and orient participants attention (Nummenmaa, Hietanen, Calvo, & Hyönä, 2011; Piech, Pastorino, & Zald, 2010). We tested whether the presence of task-irrelevant food and food-related visual stimuli may influence spatial and/or temporal parameter of our reaching movements toward a target (i.e., 'distractor effect': Howard & Tipper, 1997; Welsh & Elliott, 2004). Based on previous literature, we posited that participants would take more time to respond and/or execute the movement due to the distractor interference (see Meegan & Tipper, 1998). In addition, we also foresee possible effects of such interference in a deviation of the movement trajectory as function of the distractor location (Welsh & Elliott, 2005).

We compared the distractor effect induced by natural food, manufactured food and kitchen tools.

Additionally, participants underwent an explicit evaluation phase in which they rated the food pictures on 5 dimensions (valence, wanting, health value, hedonistic value, monetary value) and underwent an implicit assessment of food evaluation of natural and manufactured food implementing two modified versions of the Implicit association Test (IAT, Greenwald, McGhee, & Schwartz, 1998). The explicit evaluation phase and implicit assessment provided idiosyncratic indexes (i.e., specific and peculiar of each participant) that were then used to determine which food variables modulate and predict the distractor effects.

2. Method

2.1. Participants

Fifty-seven right-handed young adults (mean age = 23.2, SD = 3.1 yrs.) with normal body mass Index (*BMI-range* 18.6–24.8; *BMI-mean* = 21.6, *SD* = 1.8) took part in the study. Female sample: *N* = 37; *mean age* = 23.41, *SD* = 3.2 yrs.; *BMI-range* 18.9–24.8; *BMI-mean* = 21.2, *SD* = 1.7; male sample: *N* = 20; *mean age* = 22.9, *SD* = 3.1 yrs.; *BMI-range* 18.6–24.8; *BMI-mean* = 22.3, *SD* = 1.9. Participation was voluntary and compensation was 15 euros (circa US $17.00).

None of the participants reported specific behavioral symptoms commonly associated with risks of eating disorders on the Eating Disorder Inventory-3 (EDI-3; Garner, Olmstead, & Polivy, 1983). Inclusion criteria for the study were: (i) having an omnivorous diet; (ii) no use of neurotropic substances; (iii) no dietary restrictions for medical or religious reasons.

2.2. Stimulus material

Stimulus material comprised of 15 pictures of natural food (e.g., avocado, grapes, etc.), 15 pictures of manufactured food (e.g., meatballs, potato chips), and 15 pictures of kitchen tools (e.g., frying pan, toaster, etc.) selected from FRIDa image database[1] (Foroni et al., 2013; see selected stimuli in Fig. 1). The aim of the present experiment was not to test whether any type of stimuli could induce motor distractibility when irrelevant to the task as it was already demonstrated in previous research (i.e., Ambron & Foroni, 2015). Thus, we focus on three different stimulus categories to test whether implicit and explicit evaluation as well as food characteristics might modulate and predict the magnitude of motor distractibility.

In addition, for the IAT task, stimulus material included also 30 Italian words, 15 positive (e.g., star, life, holiday) and 15 negative (e.g., death, accident, poison). Natural and manufacture food images were selected to be matched for brightness, calorie content (per 100 g), arousal, valence, frequency in language (all $ts(28) < 1.64$, and all $ps > .1$). Similarly, the positive and negative words were matched for frequency in language, number of letters and arousal (all $ts(28) < .92$, and all $ps > .1$), but as expected they significantly differed on valence ($t(28) = 33.00$, $p < .001$).

2.3. Procedure, apparatus and data acquisition

Participants underwent a series of computer-based tasks including a (i) food evaluation session, (ii) an irrelevant distractor experiment (Ambron & Foroni, 2015; Ambron, Rumiati, & Foroni, 2015); (iii) a questionnaire session. The computer tasks were presented in a fixed order to allow unbiased assessment of the implicit and explicit association toward food. Moreover, as the primary goal was to use participants' explicit ratings and implicit-association indexes as predictors of possible motor biases, this reaching task was presented last and order was kept constant.

2.3.1. Food evaluation session

This session comprises of: (a) physiological assessment; (b) the assessment of implicit evaluation of Natural and Manufactured food via two modified Implicit Association Test (IAT; Greenwald et al., 1998); (c) Explicit evaluation of food.

2.3.1.1. Physiological assessment. In order to guarantee the assessment of influence of food-related variable on motor distractibility induced by food in a constant condition, participants were presented with a series of questions, which investigated their physiological state on five dimensions (level of hunger, thirstiness, tiredness, time encompassing from the last meal and from the last snack). For each question, they were asked to rate their state using a visual analog scale (VAS) with a correspondent score ranging from 0 to 100.

2.3.1.2. Implicit evaluation of natural and manufactured food. Participants were presented with two modified version of the IAT in which their implicit evaluation for either Natural food (Nf-IAT) or manufactured food (Mf-IAT) were assessed. IAT followed the traditional structure consisting of a total of 3 single-classification practice blocks and 2 combined test blocks (Greenwald et al., 1998).

[1] Stimulus material were taken from FRIDa database (Foroni et al., 2013) and consisted in (a) 15 Nf: almonds, avocado, banana, chestnut, coconut, corncob, dates, egg, grapes, honey, lentils, lobster, mandarin, mussel, red beans; (b) 15 Mf: carpaccio of bresaola with rocket salad, brie, candy, cooked ham with orange, dried figs, eggplant and tomato savory pie, grilled chicken breast, linguine with clams, meatballs, minestrone soup, potato chips, risotto with peas and asparagus tips, salami, shrimp, zampone; (c) 15 kitchen utensils: baking tin, beer mug, blender, bottle, chopsticks, cleaver, coffee grinder, coffee maker, frying pan, knife, salad scissors, slicing machine, toaster, waffle iron, water bottle.

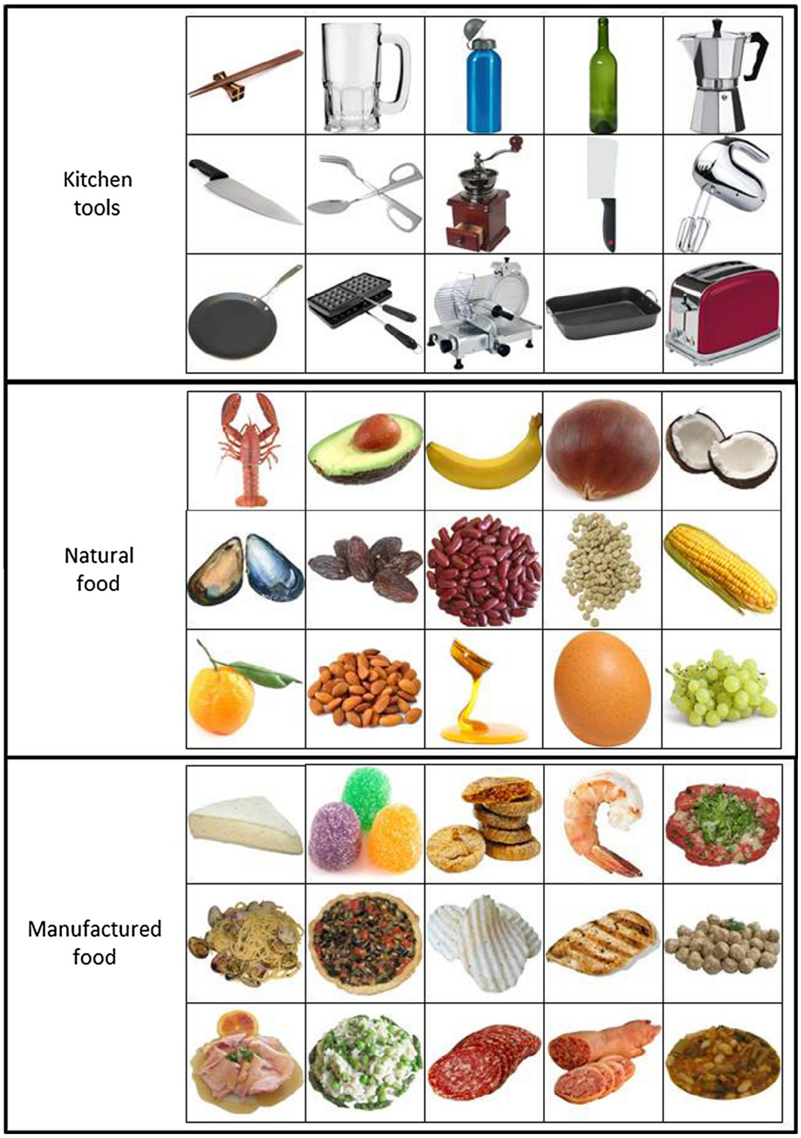

Fig. 1. Stimulus images used in the experiment by stimulus category (Kitchen tools, Natural food, and Manufactured food).

Namely, a (1) category-discrimination block between Nf [/Mf] and kitchen tools; (2) evaluative classification between positive and negative words; (3) a combined-test block including both positive/negative word evaluative classification and category discrimination between Nf [/Mf] and kitchen tools; (4) a reversed-mapping of the category discrimination block between Nf [/Mf] and kitchen tools; and (5) a reversed mapping combined-test block. Based on the response key assignment, test blocks were compatible (Nf [/Mf] and positive-words one key while tools and negative-word the second key) or incompatible (Nf [/Mf] and negative-words one key while tools and positive-word the second key). Response-key assignment and order of the compatible and incompatible blocks were counterbalanced across participants. The stimuli of the IAT comprised the 15 pictures of Nf, 15 pictures of Mf, 15 pictures of kitchen tools, 15 positive words, and 15 negative words (see Section 2.2).

2.3.1.3. Explicit evaluation of food. Participants in this part were presented with the 30 images (15 Nf and 15 Mf) of food and asked to rate each of them, in five separate blocks, using a visual analog scale (VAS) (with a correspondent score ranging from 0 to 100) on five different dimensions: *Valence* ('How negative/positive do you consider the food represented in the picture?' with the extremes of the scale labeled as 'Very negative' [0] and 'Very positive' [100]); *Wanting* ('How much do you desire in this moment the food represented in the picture?' with the extremes of the scale labeled 'I do not desire it at all' [0] and 'I desire it very much' [100]); *Health value* ('How healthy is the food represented in the picture?' with the extremes of the scale labeled 'little healthy' [0] and 'very healthy' [100]); *Hedonistic value* ('How pleasant and tasty is eating the food represented in the picture?' with the extremes of the scale labeled 'little pleasurable' [0] and 'very pleasurable' [100]); *Willingness to pay* ('how much money are you willing to spend to buy the food represented in the picture?' with the extremes of the scale labeled '10 euro-cents' [0] and '15 euros' [100] with the middle of the scale labeled '7.50 euro' [50]). Order of the dimensions and of the stimuli within each block was randomized for each participant.

2.3.2. Irrelevant distractor task

This task is a modified version of a reaching task used to explore the effect of task-irrelevant stimuli on motor action (Ambron et al., 2012; Ambron & Foroni, 2015). Implemented on a digitalized tablet laptop (display area of 260 mm × 163 mm, with the screen rotated and tilted 45 degrees), this task requires the participants to perform a simple reaching movement using a stylus. The movement needs to connect a starting point (SP; green dot, 10 mm × 10 mm) with target consisting of a similar dot (green dot, 10 mm × 10 mm) presented against a white background. The SP was placed in the lower half of the screen (centered horizontally at a distance of 15 mm from bottom edge) and the target was placed at a distance of 130 mm from the SP (see Fig. 2) to provide a good extension of the movement. The target could be presented at two possible locations: on the right or left side of the screen. However, the key aspect of this task is that an irrelevant stimulus (i.e., distractor; 40 × 40 mm) is presented at the same time as the target and placed either on the right or left side of the target. Target and distractor were arranged symmetrically around the screen midline in an arc radius of 130 mm from the SP, so that the distance between these stimuli was constant and of about 40 mm. Participants were instructed to ignore the distractor while reaching as quickly as possible the target location.

In the present experiment, the distractors stimuli were the images of 15 Nf, 15 Mf, and 15 kitchen tools (see Section 2.2). Each stimulus (40 mm × 40 mm) was presented four times (one for each target-position/distractor-position combination) for a total of 180 trials presented in a random order determined for each participant.

The coordinates of the stylus were recorded for each trial and filtered with a dual pass through a second-order Butterworth filter (cut-off of 10 Hz) and analyzed using customized software written in LabVIEW (National Instruments). Movement onset and offset were identified using a threshold of 10 mm/s on stylus speed. As result of this data processing, we extracted spatial and temporal parameters of the movement. Namely, distractor index, reaction time (RT), and movement time (MT). To compute the distractor index, we calculated first the average deviation of the movement trajectory from an ideal line connecting target and distractor for each trial for each target and distractor combination (positive values indicated deviation toward the right and negative values indicated deviations toward the left side of the ideal path). Then, we recoded these means as deviation from the distractor location, so that positive scores reflected deviations toward the distractor and negative score deviations away from its location. The final distractor index represented an overall mean deviation from the distractor collapsed across both target and distractor for each distractor category (Nf, Mf, and kitchen tools). This measure was implemented instead of peak trajectory distance from the ideal line (e.g., Sartori, Becchio, Bulgheroni, & Castiello, 2009) as it measures the movement trajectory with respect to the relative position of the distractor and reduces the impact of extreme values. This measure has been used in previous studies on this topic and proved to be a good measure of motor distractibility in this sort of paradigm (Ambron & Foroni, 2015; Ambron et al., 2012, 2015). For the temporal parameters, we obtained the RTs (i.e., time between the entrance of the stylus in the SP area and the onset of the movement), and MT (i.e., time encompassing the onset and offset of the movement).

2.3.3. Questionnaire session

Participants were also administered the EDI-3 symptoms check list questionnaire (Garner et al., 1983), normally used for evaluating symptoms commonly associated with Anorexia Nervosa and Bulimia, with the aim of identifying any participant that could eventually be at risk of eating disorders or with aberrant eating behaviors/patterns. Additionally, they also completed the Restraint Scale (Herman & Polivy, 1980), a measure assessing restrained eating habit and tendency. Finally, participants were asked to report their height and weight, to classify their eating habits (i.e., omnivore, vegetarian or vegan), and to specify if they had religious or medical restrictions to their current diet (e.g. allergies or intolerances).

2.4. Design, data preparation, and statistical analysis

2.4.1. Implicit evaluation

Data reduction for implicit evaluation of natural and of manufactured food followed the improved scoring algorithm (see Greenwald, Nosek, & Banaji, 2003) and the dependent variable was the corresponding IAT-effect expressed by Cohen's *d*′. Implicit evaluation for food in general was the average of the IAT-effect for natural and manufactured food.

2.4.2. Explicit evaluation of food

Ratings for the food items for each participant were average across food-type and dimension to create a set of indices (e.g., wanting for Nf, wanting for Mf, etc.; index for food in general is the average of the corresponding indices for Nf and Mf).

2.4.3. Irrelevant distractor task

The kinematic data were prepared and aggregated offline as described in Section 2.3.2.

2.4.4. Questionnaire session

Restrain eating score was computed following traditional computation of the whole scale (Herman & Polivy, 1980). Participants' scores on the scale were averaged together (*Mean* = 11.19, *SD* = 4.59) and this value was used to split the sample around the mean.

The results will be reported in the following order. First, we reported the data regarding the Physiological assessment (Section 3.1). Secondly, we reported the results of the Implicit evaluation of Natural and Manufactured food and of the explicit evaluations of Natural and Manufactured food (Section 3.2).

Then we explored whether movement trajectories changed across categories (Section 3.3) by a series of one-sample *t*-tests carried out on the *distractor index*es of each category (Nf, Mf, and kitchen tools). Then, we analyzed the effects of gender and restrain eating level on the *distractor indexes*. Subsequently, we analyzed the effects of gender and restrain eating level on the temporal parameters across stimuli types.

Finally, the relative contribution of idiosyncratic indices and variables to spatial and temporal parameters of the movement were tested by a series of backward multilinear regressions (Section 3.4). Three regression models were constructed using each one of the kinematic indices for Nf as dependent variable (i.e., *distractor effect*, *RT*, and *MT*; Section 3.4.1). Independent variables that were included in the full model of these three regressions were participant's own ratings: ratings of valence of Nf, ratings of wanting for Nf, ratings of Nf health value, ratings of Nf hedonic value, willingness to pay for Nf, implicit evaluation (Nf-IAT), and individual's restrained eating score. Three more regression models were constructed for Mf distractors (Section 3.4.2). In these latter three models the independent variables that were included were the same ones as before but were specific to Mf (i.e., Mf participant's own ratings). In these models the individual restrained eating score was the same and was also included as predictor. The most parsimonious multiple regression models were constructed by backward elimination of the no-significant variables ($p > .1$). Statistical significance was inferred for $p < .05$.

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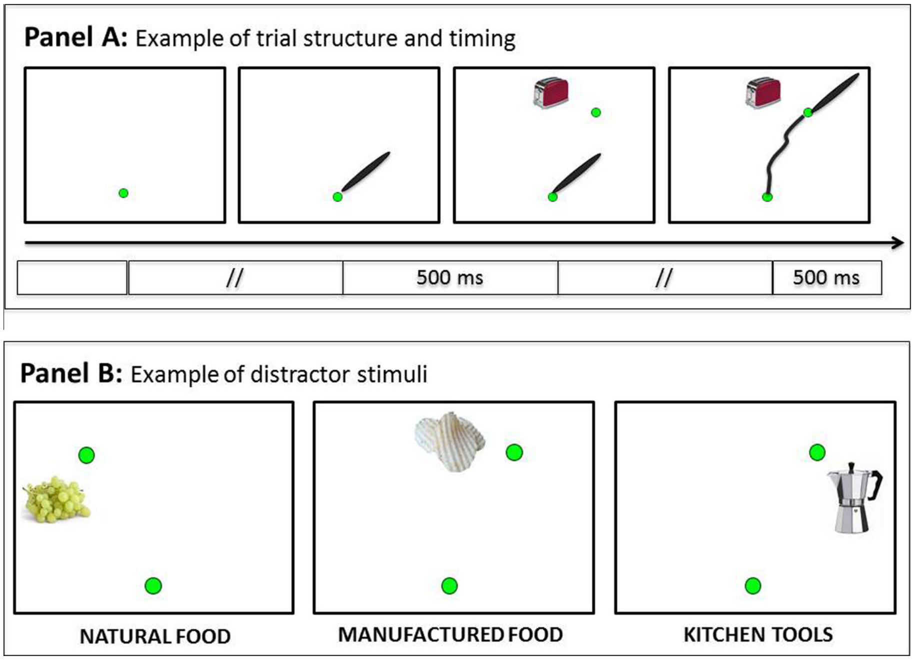

Fig. 2. *Panel A* shows the series of events of a trial. *Panel B* shows examples of different categories of stimuli and possible target locations.

3. Results

3.1. Physiological assessment

Participants' responses on the physiological assessment indicated that on average they had their last sneak approximately 2 h before the experiment (*M* = 35.1, *SD* = 33.1) and their last meal approximately 3 h before the experiment (*M* = 59.9, *SD* = 38.0). However, the responses indicated that they were not angry (*M* = 20.2, *SD* = 24.4), not thirsty (*M* = 33.4, *SD* = 23.3), and not tired (*M* = 36.3, *SD* = 29.1).

3.2. Implicit and explicit evaluation of natural and manufactured food

Participants showed a significant implicit association between positivity and both Natural food (*M* = .59, *SD* = .36) and Manufactured food (*M* = .60, *SD* = .33) as evidenced by the significant difference with 0 of the mean *d′* ($t(56) = 12.29$, $p < .001$ and $t(56) = 13.82$, $p < .001$, respectively). As one could expect, participants show consistently a significant association between positivity and food compare to kitchen tools. Table 1 reports the average explicit ratings of Natural and Manufactured food.

3.3. Distractor effects

3.3.1. Distractor effect on spatial aspects of movement

Across distractor categories, the presence of task-irrelevant stimuli influenced the reaching trajectory, which veered significantly toward the distractor location as shown by a significant one sample *t*-test (against 0) performed on the overall *distractor index* (*M* = .16, *SD* = .18; $t(56) = 6.6$, $p < 0.001$). When looking at the *distractor index* (Bonferroni-corrected for multiple comparison) separately for each distractor category, we found that the distractor indexes differed from zero for each category: kitchen tools (*M* = .14, *SD* = .26; $t(56) = 4.3$, $p < 0.001$), Nf (*M* = .20, *SD* = .27; $t(56) = 5.56$, $p < 0.001$) and Mf (*M* = .15, *SD* = .27; $t(56) = 4.13$, $p < 0.001$). However, when looking at possible differences between categories across gender and restrain eater level (high (>11.19) vs. Low (⩽11.19)) the *distractor index* appeared of a similar magnitude across categories (*Fs* $(2,52) < 1.95$, *ps* ⩾ .15, $\eta^2 < .071$). Interestingly, no habituation effect was found. Namely, the magnitude of the distractor effect did not change from early vs. later trials as shown by an ancillary analysis. We use block (Block1, Block2, Block3) and stimulus type (Nf, Mf, Kitchen tools) as within subject-factors and we tested whether over time the magnitude of distractor effect changed. The main effect of stimulus type was not significant (as was not in our original analyses), $F(2,55) = .85$, $p = .43$. No significant change over the three blocks was observed in the magnitude of the distractor index ($M_{bl1} = .17$, $M_{bl2} = .12$, $M_{bl3} = .20$), $F(2,55) = 2.32$, $p = .11$. This was similarly true for each stimulus type as shown by the non-significant interaction, $F(3.5,193.93) = .22$, $p = .90$ (Greenhouse–Geisser corrected for violation of Sphericity)[2].

Table 1
Average (Standard deviations) for explicit rating of food items on valence, wanting, health value, hedonic value, and willingness to pay. Ratings were done using a visual analog scale (VAS) with a correspondent score ranging from 0 to 100. Table reports also whether the two types of food were rated significantly different from each other.

	Natural food	Manufactured food
Valence	69.29 (14.27)	65.80 (13.93)°
Wanting	37.84 (16.67)	42.36 (20.53)°
Health value	73.61 (12.00)	47.10 (8.19)**
Hedonic value	57.10 (15.88)	60.46 (12.49)
Willingness to pay	19.11 (10.13)	29.19 (11.39)**

** $p < 0.001$.
° $p = 0.06$

3.3.2. Distractor effect on temporal aspects of movement

We then looked at the temporal parameters of the action across gender and restrain eater level (high (>11) vs. Low (⩽11)).

Reaction times. The data showed no differences in term of *RTs* (*Fs* $(2,52\text{–}84) < 2.6$, *ps* > .09, $\eta^2 < .048$).

[2] We thank an anonymous reviewer for suggesting to test for such possibility.

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Table 2
Determinants of kinematic variables for Nf (distractor effects, RT, MT, TPV respectively) with backward selection. Predictors are: Nf valence, Nf wanting, Nf health value, Nf hedonic value, willingness to pay for Nf, implicit preferences for Nf, and participant restrained eating score.

	B	SE B	Beta
Regression 1. DV: Average distractor index for natural food (Nf)			
Hedonic value Nf (p = .033)	−.007	.003	−.419
	Model R^2 = .119, F(7,56) = .950, p = .478		
Regression 2. DV: Average RT for natural food (Nf)			
Valence Nf (p = .038)	−1.713	.802	−.350
Willingness to pay Nf (p = .04)	1.837	.872	.266
	Model R^2 = .258, F(7,56) = 2.438, p = .032		
Regression 3. DV: Average MT for natural food (Nf)			
Valence Nf (p = .002)	−6.287	1.928	−.530
Health value Nf (p = .068)	4.118	2.209	.292
	Model R^2 = .236, F(6,56) = 2.580, p = .030		

Table 3
Determinants of kinematic variables for Mf (distractor effects, RT, MT, TPV respectively) with backward selection. Predictors are: Mf valence, Mf wanting, Mf health value, Mf hedonic value, willingness to pay for Mf, implicit preferences for Mf, and participant restrained eating score.

	B	SE B	Beta
Regression 4. DV: Average distractor index for transformed food (Mf)			
Mf-IAT (p = .014)	−.283	.110	−.334
Health value Mf (p = .016)	−.012	.005	−.363
	Model R^2 = .225, F(6,56) = 2.42, p = .039		
Regression 5. DV: Average RT for transformed food (Mf)			
Willingness to pay Mf (p = .05)	1.410	.703	.269
	Model R^2 = .200, F(5,56) = 2.54, p = .039		
Regression 6. DV: Average MT for transformed food (Mf)			
Valence Mf (p = .023)	−4.315	1.839	−.354
Health Value Mf (p = .052)	5.848	2.935	.282
	Model R^2 = .201, F(5,56) = 2.54, p = .038		

Movement time. When looking at the results relative to *MT*, a significant main effect of the category was observed ($F(2,52) = 3.41$, $p = 0.04$, $\eta^2 = .116$), driven by the longer *MT* for Mf ($M = 631$, $SD = 170$) compared to kitchen tools ($M = 623$, $SD = 168$; $p = 0.013$) and to Nf ($M = 626$, $SD = 169$; $p = 0.038$). Kitchen tools and Nf did not differed from each other ($p = 0.71$). No other significant effects were found ($Fs\ (2,52) < 2.2$, $ps > .13$, $\eta^2 < .08$).

3.4. Predicting distractor effects with participant's own evaluations

We now turn to look at the possible impact of each participant's own ratings and characteristics on distractor effects for Nf and Mf.

3.4.1. Predicting distractor effects induced by Nf

Table 2 reports the statistical results of the kinematic indices for Nf distractors. When looking at Nf *distractor index* (Regression 1), we found that although the final model did not reached significance level, the hedonic value of natural food was found to be a significant predictor of the distractor index. The least Nf is considered pleasurable the most distraction induces ($p = .033$).

For the two temporal parameters of the movement (*RTs* and *MT*) each regression model was statistically significant (Regressions 2 and 3, respectively). The increase in *RTs* was predicted by the increase in willingness to pay for Nf items ($p = .04$) and the decrease in valence ($p = .038$). *MT* was predicted negatively by valence ($p = .002$) and showed a marginal tendency (albeit not statistically significant, $p = .068$) to be positively predicted by health value. Participants will be more prone to respond quickly (*RTs*) to Nf the more they rate it positively and the least they are willing to pay for it. However, participants take less time in executing the action (*MT*) if they rate Nf more positively and consider this type of food as less healthy.

3.4.2. Predicting distractor effects induced by Mf

When looking at the kinematic parameters for Mf distractors (Table 3) the regression analyses showed different results.

For Mf *distractor index*, the regression model was statistically significant (Regression 4). In this case, and differently from Nf, both the Mf-IAT score and the health value were significant predictors ($p = .014$ and $p = .016$ respectively). Namely, the tendency to veer toward the distractor is more likely to emerge if the food is implicitly held as more negative and considered less healthy.

For the two temporal aspects of the movement (*RTs* and *MT*) each regression model was statistically significant (Regressions 5 and 6, respectively). The increase in *RTs* here was predicted only by the increase in willingness to pay for Mf items ($p = .05$). Instead, valence evaluation ($p = .023$) and the health value ($p = .05$) were significant predictors of *MT*. Similarly to Nf, also for the Mf, participant were likely to exhibit more prone responses for Mf distractors the least they are willing to pay for this type of food. Furthermore, they were likely to spend less time to execute the movement, if they rated Mf more positively and less healthy.

4. Discussion and conclusions

In our food-rich environment we are exposed to infinite number of food stimuli that may grab our attention and influence our ongoing actions (Nummenmaa et al., 2011). In order to test the

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distracting role of food, in the present study we implemented a reaching paradigm where participants had to reach a target while ignoring a distractor image of food or food-related items (e.g., Ambron et al., 2012). In this type of paradigm, the presence of salient distractor stimuli has been found to influence spatial aspects of the trajectory, the so called 'distractor effect' in reaching (Tipper, Howard, & Jackson, 1997; Welsh & Elliott, 2004, 2005), even when distractor are irrelevant to the task at hand (Ambron & Foroni, 2015). We measure changes of both spatial (movement trajectory) as well as temporal parameters movement, such as delayed initiation (here called RTs) and/or execution of the movement (movement time: MT) related to the presence of a task-irrelevant stimulus.

We explored whether different types of food (Nf and Mf) and food-related objects could modulate unrelated reaching movements and we tested whether these effects are modulated by participants' own evaluations of food items at the implicit and explicit level, as well as by participants' tendency to restrain their diet (Herman & Polivy, 1980). Our results provide important hints in these regards and we will discuss them in turn.

First, when looking at the spatial aspect of the reaching trajectories (i.e., deviation of the trajectory from the distractor location), we found that participants' movement trajectories veered toward the location of food and food-related distractors. This finding reinforced the idea that food and food-related stimuli are powerful attentional-capturing cues and strong sources of interference with ongoing actions even if irrelevant to the task. This is in line with evidence that task-irrelevant distractors if salient to participants (e.g., co-species displaying emotional expression but not-neutral expressions; Ambron & Foroni, 2015) are difficult to inhibit (Welsh & Elliott, 2004; 2005). Thus, our perceptual and attentional systems may provide preferential access to classes of stimuli with high significance for the organism (Öhman, Flykt, & Esteves, 2001). We showed that food is one of them and this is probably due to its high biological salience (see Killgore et al., 2003; Santel, Baving, Krauel, Munte, & Rotte, 2006; Simmons et al., 2005). Previous research demonstrated that involuntary orienting responses are induced during processing food and food-related stimuli (Watson & Garvey, 2013) exactly because of their salience (e.g., Nijs, Franken, & Muris, 2008; 2009). Our results go beyond that and show that food does even more by influencing our motor responses even if irrelevant to the goal-directed action.

Secondly, we were also particularly interested in exploring each food class independently, to investigate whether different pattern of motor distractibility could be observed. The relevance of the distinction between Nf and Mf is derived from the evolutionary role that food processing may have played (Wrangham, 2009; see also Rumiati & Foroni, 2015). However, the magnitude of the spatial bias did not show any systematic difference between Nf and Mf. Since food has intrinsic reward properties, it seems that both types of food (as they were carefully equated for calorie content) have similar saliency for the participants. This result is in line with previous work on selective attention of food items. For instance, Nummenmaa et al. (2011) demonstrated that participants were faster in identifying food items then non-food items, but this effect was not modulated by the reward property of the food.

Thirdly, we investigated temporal parameters of the movements (RT and MT). Differently from spatial parameters of the movements, in term of temporal parameters, participants took more time to execute the reaching movement (MT) when the distractors were Mf stimuli in comparison to Nf and kitchen tools. This result indicates that the classes of stimuli differ in their ability and power of producing interference suggesting that Mf is more salient than Nf and kitchen tools. The difference between Mf and Nf on this aspect is particularly interesting. The two classes of stimuli were matched for several relevant dimensions (i.e., calorie content per 100 g, valence, arousal, and frequency in language), and thus, this significant difference supports the importance of the Nf–Mf distinction (e.g., Rumiati & Foroni, 2015) at least on the temporal aspect of the distractor effect.

Fourth, we investigate whether participants' own implicit and explicit evaluations of food predict the spatial and temporal aspects of the distractor effect. Most interestingly, we found that the *distractor-index* induced by different types of food is systematically and differently predicted by participants' own evaluations of the food. While for Nf the distractor effect on the movement trajectory is predicted by the hedonic value attributed by the participant to Nf (albeit the model did not reach significance), the bias in movement trajectory in the presence of Mf is predicted by participants' implicit attitudes toward Mf and by how participants rated the healthiness of Mf (here supported by a significant model). The allocation of selective attention on food has been associated to hedonic thoughts in previous research but the present results go against previous theorization (Lang, Bradley, & Cuthbert, 1997), as we found that participants display a larger deviation of the trajectory in the presence of Nf when they attributed lower hedonic value to the Nf. The lack of strong statistical support for this result calls for caution in interpreting the inconsistency with previous literature.

More interestingly, however, is the fact that the more a participant considers negatively Mf at the implicit level and un-healthy at the explicit level, the larger deviation toward the distractor is likely to display. This tendency of negativity (more negative and less healthy) to induce larger distraction was also reported in the domain of emotion where task-irrelevant angry expressions induced the largest distractor effect (e.g., Ambron & Foroni, 2015) and is in line with the observation that attention is automatically driven toward dangerous situations (Vuilleumier, 2005; Öhman et al., 2001). We can speculate that the negative evaluation of food may alert individuals and orient rapidly participants' attention toward this set of stimuli as potential source of danger for the organism, producing a similar response to the one observed for threatening stimuli (e.g., angry faces) and enhancing the probability of distractor effect (Ambron & Foroni, 2015).

However, attentional processing during our tasks were inferred on the basis of the motor behavior but were not corroborated by the assessment of eye movements that might have provided additional control on whether or not participants looked at (and overtly attend at) the distractor during the task, providing also important information regarding the distractor effect toward food items. As the distractor effect in saccadic movement has been widely reported (e.g., Walker, McSorley, & Haggard, 2006), the possible interaction between saccadic and hand movements in the distractor effect with food and non-food items is still matter of investigation and would be a key topic for future studies.

The role of implicit attitudes in determining the magnitude of the bias is interesting as automatic evaluations are assumed to predispose the organism to spontaneously approach or avoid relevant stimuli (e.g., Chen & Bargh, 1999; Neumann, Hülsenbeck, & Seibt, 2004), thus providing a fast and efficient means of behavioral orientation in the environment: namely, approaching for positive and avoiding what is negative (Hofmann, Rauch, & Gawronski, 2007). In line with this argument, rewarding stimuli have been shown to induce preparation of motor responses (Veling & Aarts, 2011). However, here we report that the Mf that we evaluated more negatively at the implicit level captures our attention and influenced our actions the most, inducing a deviation of motor trajectory toward it. When irrelevant to the ongoing motor action, negative Mf results in larger distraction inducing our action to veer toward it and, thus, paradoxically increasing the likelihood of its ingestion

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(Maas, de Ridder, de Vet, & De Wit, 2012). This interpretation is supported by evidence for spatial discounting, namely, choosing between less rewarding items close by versus more distant rewards (cf. Mühlhoff, Stevens, & Reader, 2011).

On one hand, this could be due to the fact that automatic approach tendencies and affective associations may diverge under certain conditions (e.g., Zinbarg, 1998). On the other hand, implicitly negative Mf may be functioning as negative emotions, such as they might represent high source of attentional capture as they represent potential threatening stimuli. High-level attentional capturing and monitoring might be directed toward negative food items in order to protect and guarantee the survival of the organism (Palermo & Rhodes, 2007). Such attention enhancement of negative food items may be rather difficult to inhibit causing a distractor effect for these types of stimuli. Interestingly this occurs only for Mf supporting the distinction between Nf and Mf (Rumiati & Foroni, 2015).

For both natural and manufactured food participants' valence and health explicit ratings, instead, predicted (negatively and positively, respectively) the temporal aspects of the reaching movements: namely, the less positive and the more healthy a food is explicitly considered, the more time participants will be likely to take for executing the movement. This evidence suggests that larger distractor interference on the temporal parameters of the action are likely to be observed when participants have a negative attitude toward the food but value more the food in term of healthiness.

One interesting and robust result that calls for further investigations is the predicting power of 'willingness to pay' that we observed for RT when before both natural and manufactured food. Participants take more time to start an action when they are 'willing to pay' more for the '*distractor*'. Notably, in previous research 'willingness to pay' has been associated to calorie content of food (Tang et al., 2014), but here Nf and Mf are matched for calorie content and participants show similar initiation time before both. We could speculate that if participants are 'willing to pay' more for a specific type of food, because they somehow value it highly, they might be more distracted by it and, thus, they tend to respond more slowly as part of more sophisticated and thoughtful decision process.

Notably, neither the wanting nor the hedonic ratings showed any systematic predicting power of the distractor effects even though these variables were identified by several authors as key factors guiding our interaction with food (e.g., Hoefling & Strack, 2008; Papies, Stroebe, & Aarts, 2009). The present results suggest that they do not modulate early attentional processes captured by the present paradigm and this notion should be taken into account in future theorization.

Another relevant result of the present study was that gender of the participants and the level with which participants restrain their diet do not modulate the distractor effects. In previous research these dimensions were found to modulate food-related effects (e.g., Brunstrom, Yates, & Witcomb, 2004; Fedoroff, Polivy, & Herman, 2003; Watson & Garvey, 2013). It is indeed possible that the distractor effects reported here are more general. However, the limited number of male participants in our sample should be kept into consideration and future research should investigate the possible moderating role of gender on distractor effects. The lack of modulating effects induced by the level of restrain of the diet is partially different and it is apparently at odd with previous research. For instance, some authors reported that restrained eaters compared to unrestrained eaters display greater Stroop interference on food words (Francis, Stewart, & Hounsell, 1997; Stewart & Samoluk, 1997) and increased visual attention to food cues (Papies et al., 2008a). Notably, research on the role of eating restraint in directing selective attention toward food has led to equivocal results with several studies reporting no evidence of such attentional bias in dietary restrain eaters (for a review, see e.g., Dobson & Dozois, 2004; see also Watson & Garvey, 2013). This null effect may be due also to the features of our paradigm as it provides very different insights. It focuses on the potential role of task-irrelevant food distractors in grabbing our attention (Ambron et al., 2012; Ambron & Foroni, 2015) and influencing our motor actions. In this sense it departs from paradigms aimed at assessing motivated shifts of selective attention. Thus, the present findings, like the one reported by Watson and Garvey (2013), may be related to "earlier aspects of attention to food-related stimuli" (p. 46) involving more automatic attentional capturing mechanisms.

4.1. Implications and future direction

The results reported here implementing a task-irrelevant distractor paradigm suggest that food and food cues interfere with our actions even when irrelevant for our on-going activity and that different characteristics of natural and manufactured food moderate such effects.

The present paradigm, as it involves simple reaching movements in the presence of different types of distractors, was not set up to test possible effects of different affordances induces by the specific distractors (e.g., Castiello, 1999). In fact, within each distractor category the stimuli were not selected based on this issue and no direct grip-aperture measurement was possible in the present paradigm. Nevertheless, future research should address this interesting possibility.

However, the paradigm is a suitable tool to investigate also special populations otherwise difficult to assess such as children (see e.g., Ambron et al., 2012) and patients with eating disorders (e.g., obese, anorexic, and bulimic) in order to assess early attentional bias and the consequent distracting role of different types of food. There is a growing literature demonstrating that anorexic and bulimic patients exhibit an attentional bias toward food-, weight-, and shape-related information as well as a memory bias for such information (for a review see Fedoroff et al., 2003) but no research so far investigated these populations and the downstream motor-implications of such attentional biases. In this regard, a special mention should be done about the Body Mass Index (BMI: World Health Organization, 2006) of our sample. Participants in our sample were of normal BMI and follow up analyses did not find any relation between the BMI and the distractor effects. Future investigations should extend the BMI range to investigate if this dimension also modulates attentional processes and the resulting motor distractibility.

Finally, it is important to note also that the present paradigm may even downplay the possible role that automatic stimulus-driven attention might play in our interaction with a food-rich environment. In fact, in our paradigm, the distractors appeared in predictable locations and thus should be easy to ignore; moreover, our sample of participants reported low levels on our physiological questions (e.g., hunger, thirst, tiredness, etc.). Follow-up analyses, indeed, did not find any relation between these measures and the distractor effects. However, distraction may be much larger when distractors are unexpected and in unpredictable locations – as occurs in daily-life situations – and cognitive abilities are reduced as consequence of stress (Sato, Takenaka, & Kawahara, 2012) and/or in aroused physiological states like hunger.

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