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Fear signals inhibit impulsive behavior toward rewarding food objects☆

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ABSTRACT

We examined whether presentation of environmental cues that are associated with motor inhibition, i.e., fearful facial expressions, can be effective in controlling unintentionally evoked impulses toward rewarding food objects. Participants were presented with palatable foods or control objects. During presentation of the objects, facial expressions displaying fear, disgust, or neutral emotion were shortly presented. Results show that presentation of fearful facial expressions together with palatable foods slowed down subsequent responding to action probes, but only for participants who perceive palatable foods as highly rewarding and impulse-evoking, i.e., restrained eaters. Facial expressions of disgust did not show this effect. This finding suggests that unintentionally evoked motor impulses toward rewarding objects are inhibited upon presentation of a fear signal. The present research provides new insight on how emotional signals may be used to control impulsive responses toward palatable foods by the environment.

Introduction

Maintaining a healthy low-calorie diet can be quite a difficult endeavor, as is suggested by rising numbers of people with obesity (e.g., WHO, 2000). Consensus is growing that one important contributor to this difficulty is the food-rich environment where high-calorie foods are very visible and easily available (e.g., Hill & Peters, 1998; Stroebe, 2008; Wilson, 2010). High-calorie palatable foods have a high reward value for many people, especially among those who are restrained eaters (e.g., Davis, Strachan, & Berkson, 2004; Hofmann, Van Koningsbruggen, Stroebe, Ramanathan, & Aarts, 2010; Papies, Stroebe, & Aarts, 2007; Wilson, 2010), and perception of rewarding objects can unintentionally (i.e., upon mere perception of these objects) elicit motor impulses to obtain these objects (Veling & Aarts, in press-b). Such impulses may facilitate consumption of palatable foods, particularly when conscious or intentional processes are taxed (e.g., Hofmann, Friese, & Wiers, 2008; Nederkoorn, Houben, Hofmann, Roefs, & Jansen, 2010; Stirling & Yeomans, 2004). Hence, one way to improve control of impulsive behavior toward rewarding food objects may be by inhibiting these unintentionally evoked impulses by environmental cues before these impulses materialize and guide overt eating behavior.

Surprisingly, however, there is not much research available that has addressed how such environmentally driven inhibition may be accomplished. In the present research we aim to provide new insight into this question by examining whether emotional cues, fearful facial expressions in particular, can be used to inhibit motor impulses toward rewarding palatable food objects. Furthermore, we aim to demonstrate that restrained eaters (who perceive palatable food as more rewarding) may benefit more strongly from this environmentally driven inhibition toward palatable food.

Recently, it has been suggested that inhibition of unintentionally evoked motor impulses upon perception of rewarding objects may be accomplished by presenting behavioral stop signals near these objects (Veling & Aarts, 2009; Veling & Aarts, in press-a; Veling, Holland, & van Knippenberg, 2008). A stop signal is a cue in the environment that causes people to inhibit their behavior by suppressing any evoked motor impulses (e.g., Coxon, Stinaer, & Byblow, 2006; Stinear, Coxon, & Byblow, 2009). This suppression of motor impulses has been shown to inhibit the motor system globally, which can be viewed as a brake on all subsequent responses. In other words, after inhibiting motor impulses restarting of subsequent behavior is slowed down. Thus, presentation of a stop signal near rewarding impulse-evoking objects may lead to motor inhibition that inhibits the initially evoked impulse and prevents behavior from overtly occurring. We recently tested this hypothesis in the domain of drinking behavior.

Specifically, participants were presented with go and no-go cues (i.e., the stop signals) that were displayed near rewarding objects (e.g., drinks for thirsty participants) and control objects (Veling & Aarts, in press-b). The task was simply to press a button when a go cue was presented and withhold responding when a

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no-go cue was presented. Importantly, participants were also instructed to respond as fast as possible to action probes that occasionally, and unpredictably, appeared after the object-cue combinations. This allowed us to measure motor inhibition of unintentionally evoked impulses after presentation of no-go cues with rewarding objects and no-go cues with control objects. Results showed that presentation of no-go cues with rewarding objects indeed slowed-down responses to the action probes suggesting inhibition of the unintentional impulses. Further experimentation showed that rewarding objects that were consistently accompanied by no-go cues not only caused participants to respond more slowly toward action probes; but also to respond less eagerly toward these objects upon sudden exposure (Veling & Aarts, 2009). Together, these findings suggest that presentation of stop signals near rewarding objects puts an inhibitory brake on the action system that slows down and regulates the occurrence of unintentionally evoked impulses toward rewarding objects.

The research described above suggests that stop signals may be an effective tool to control behavior toward impulse-evoking rewarding food objects. This hypothesis has recently been tested by Houben and Jansen (2011) in a study, in which rewarding foods (i.e., pictures of chocolate for high trait chocolate cravers) were repeatedly and consistently associated with no-go cues for participants in the experimental condition. In the control condition no such association was established. Next, they measured consumption of chocolate in a taste test. Results showed that compared to the control condition, participants in the experimental condition consumed less chocolate. Importantly, this effect was stronger for participants who have been shown to react very impulsively toward rewarding food objects (i.e., restrained eaters; e.g., Fedoroff, Polivy, & Herman, 1997; Jansen & Van den Hout, 1991; Papies & Hamstra, 2010). The results of this study are thus consistent with prior work revealing that stop signals (i.e., no-go cues) inhibit impulsive responses after they have been presented near rewarding impulse-evoking objects (Veling & Aarts, 2009), and show that stop signals can even reduce actual food intake.

So far research used stop cues that need to be learned. It would naturally be an advantage from the point of view of practical application, if we could do without such learning trials by using ecological inhibitory signals. Thus, in the present research we aimed to move one step further by examining impulsive responses toward rewarding or palatable food, and to test whether these unintentionally evoked food impulses can be inhibited when an intrinsic stop signal is used instead of an experimentally created stop signal. Such a demonstration would not only provide new theoretical insights into the possibilities of controlling impulsive eating behavior by environmental cues in general, but also provide a starting point for thinking about new ways to inhibit undesired motor impulses in the environment (e.g., by presenting intrinsic inhibitory signals in environments where undesired impulsive behaviors are observed).

To accomplish this goal we examined whether presentation of fearful facial expressions inhibits the motor system when presented near rewarding food objects. We selected fearful facial expressions as an intrinsic inhibitory signal for two reasons. First, previous work suggests that perception of negative stimuli can inhibit the motor system, especially when these negative stimuli are incidentally encountered (e.g., Fanselow, 1994; Wilkowski & Robinson, 2006). Importantly, in the context of negative emotional stimuli, fearful stimuli have most strongly been associated with motor inhibition (i.e., as in freezing; e.g., Adams, Ambady, Macrae, & Kleck, 2006; Butler et al., 2007; Fanselow, 1994; LeDoux, 1996; see also Amodio, Master, Yee, & Taylor, 2008). Moreover, compared to faces displaying disgust, perception of fearful faces causes stronger activation in brain areas that have been implicated in inhibition of prepared responses such as the dorsolateral prefrontal cortex (dlPFC; Phillips et al., 1998). We currently tested whether perception of fearful faces would indeed inhibit prepared responses upon perception of rewarding food objects.

Second, facial expressions were used as fearful stimuli because these faces are unambiguously related to fear, and faces communicate emotional significance very rapidly (e.g., Blair, 2003). We compared the inhibitory effects of fearful facial expressions with both neutral facial expressions, and another high arousal negative facial expression, i.e., facial expressions displaying disgust. The facial expression of fear as well disgust have been shown to be associated with negative evaluations (Aarts et al., 2010; Barthomeuf, Roussett, & Droit-Volet, 2009; Boksem, Ruys, & Aarts, in press). Accordingly, fear and disgust can both alter evaluative responses to stimuli. However, unlike fear signals, disgust stimuli are not related to motor inhibition (e.g., Ferri et al., 2010; Oliveri et al., 2003). From the perspective of controlling impulsive responses to tempting stimuli, then, fear seems to have additional merits in putting impulsive action on hold. We thus included faces displaying disgust to rule out the hypothesis that any arousal-related negative facial stimulus would inhibit motor responses, and to offer a first demonstration of the unique role of fearful facial expressions in inhibiting impulsive behavior.

To test these hypotheses, participants were presented with palatable foods or control objects that were sometimes followed by an action probe. During presentation of these objects a facial expression displaying fear, disgust or neutral emotion was presented. We manipulated specificity of the negative emotional expression (i.e., fear versus disgust) between participants to test the effects of these emotional cues independently of one another. When unintentionally evoked motor impulses are actively inhibited by fearful facial expressions, responses to the action probes should be slowed down after presentation of palatable foods with fearful facial expressions (i.e., because motor inhibition puts a brake on subsequent action). Moreover, this motor inhibition should be stronger as palatable foods are more impulse-evoking, i.e., as the strength of motor inhibition has been shown to be a function of the strength of the initially evoked impulse (e.g., Nakata et al., 2006). To test this, we also asked participants to fill out the restraint eating scale (Herman & Polivy, 1980). Research has clearly shown that palatable foods are particularly rewarding and impulse-evoking for restrained eaters, i.e., participants that score relatively high on this scale (e.g., Brunstrom, Yates, & Witcomb, 2004; Jansen & Van den Hout, 1991; Hofmann et al., 2010; Houben, Roefs, & Jansen, 2010; Papies et al., 2007; Papies & Hamstra, 2010; Stirling & Yeomans, 2004). Hence, the inhibitory effect of fearful facial expressions should especially be found for participants who score high on the restraint scale. Such a result would also be consistent with the findings of Houben and Jansen (2011) discussed earlier, that experimentally created stop signals are most effective in reducing impulsive behavior toward palatable foods in restrained eaters.

In sum, we expected a four way interaction between object type (palatable food versus control) facial expression (emotional versus neutral) type of negative expression (fear versus disgust) and restrained eating, such that responses to the action probes would be slowed down after perception of palatable foods with fearful facial expressions for restrained eaters.

Method

Participants and design

Sixty undergraduates (49 women) received 2 € for their participation. We employed a 2 (object type: palatable food versus control) by 2 (facial expression: emotional versus neutral) by 2 (type of negative expression: fear versus disgust) mixed subjects design with object type and facial expression as within subject factors and type of negative expression manipulated between subjects. Moreover, we included dietary restraint as a continuous predictor.

Stimuli

We selected eight pictures of high-calorie palatable food objects (e.g., chocolate, ice-cream, cookies, pizza, cake) comparable to those used in previous research on restrained eating (e.g., Papies, Stroebe, & Aarts, 2009). As control object we used a grey circle (see also Veling & Aarts, in press-b). Facial expressions were selected from the NimStim Set of Facial Expressions (Tottenham et al., 2009; picture codes for the fearful, neutral and disgust expressions are, respectively, 03F_FE_O, 03F_NE_C, and 03F_DI_C).

Restraint eating scale

Participants were asked to fill out the Concern for Dieting subscale of the Revised Restraint Scale (Herman & Polivy, 1980; Jansen, Oosterlaan, Merckelbach, & van den Hout, 1988). This scale has been used in earlier studies on the implicit processes of restrained eating and has been recommended to identify participants' chronic motivation to control their weight by dieting (Blanchard & Frost, 1983; Papies & Hamstra, 2010; Stroebe, Mensink, Aarts, Schut, & Kruglanski, 2008). The scale assesses participants' motivation to restrain their eating by six items such as "How often are you dieting?" and "How conscious are you of what you are eating?" (Cronbach's α = .78).

Procedure

Participants received a go/no-go task, and were asked to respond as accurately and quickly as possible to go and no-go cues that would appear on the computer screen in combination with other stimuli. The go and no-go cues were the signs "*" and "=", respectively, and they were presented in blue font type. Reaction times to the go cues (i.e., the action probes) served as our dependent variable.

Each trial started with a fixation point that was presented for 400, 500 or 600 ms. Next, a food or control object was presented, and 200 ms after object onset an emotional or neutral face briefly appeared either to the left or right of the object for 100 ms. The objects remained on screen during presentation of the face. Then, the object and face disappeared from screen, and either a go or no-go cue appeared that required a response (pressing the space bar with the index finger) or withholding a response, respectively. These cues were displayed for either 1500 ms, or until the participant responded. We included 50% no-go trials in the present task to avoid intentional preparation of responses before onset of the go and no-go cues (Braver, Barch, Gray, Molfese, & Snyder, 2001). After a correct (non) response a green circle was presented, and after an erroneous (non) response a red cross was presented for 500 ms. Moreover, and to encourage fast responding, we also displayed the response time after correct go trials. The intertrial interval was 500 ms.

The go/no-go task consisted of 5 experimental blocks of 16 trials (excluding the filler trials described below). Within each block, each food object was presented once and the grey circle was presented eight times. In 50% of the trials an emotional expression appeared near the object, and in 50% a neutral expression appeared. These facial expressions were in 50% of the trials presented to the left of the objects, and in 50% of the trials to the right of the objects. Moreover, in 50% of the trials a go cue was presented, and in 50% a no-go cue. Selection of one of the object types (food or control), facial expressions (emotional or neutral), locations of the face (left or right of the object), and cue types (go or no-go) was random with the constraints that a specific stimulus (e.g., food object, emotional expression, right location, go cue) was not presented more than four times in a row, and that each combination that can be made of the four variables (i.e., object type, facial expression, location of the face, cue type) was presented once within each block.

In addition, we also presented 16 filler trials randomly throughout the task, in which a go or no-go cue was presented immediately after the fixation point (i.e., no object and face was presented on these trials). We included these filler trials to ensure that participants would attend to the screen after the fixation point, and process the task-irrelevant objects and faces. Before starting the test blocks participants received a practice block including only a neutral face (this face was different from the neutral face used in the experimental blocks), and with common non-food objects. Afterwards, participants were debriefed and thanked for their participation. None of the participants reported any suspicion of the true nature of the study.

Results

Participants made 2% errors (i.e., omissions and erroneous responses) in the go/no-go task. Action probe trials (i.e., the go trials) with responses faster than 150 ms (0.02%), and omissions were removed, and we conducted analyses on mean reaction times on the action probe trials. Analyses are also reliable when log-transformed means are used. Analyses showed that location of the face (left or right), and sex of the participants did not have any reliable effects, and these factors were therefore dropped from the analyses. There was no reliable difference between restraint scores in the fearful negative facial expression and restraint scores in the disgust negative facial expression condition, $F < 1$.

To test whether fearful facial expressions inhibited action toward rewarding food objects, we analyzed response latencies on action probe trials (i.e., the go trials) in the General Linear Model including the effects of object type (palatable food versus control), facial expression (emotional versus control), type of negative expression (fear versus disgust), restraint, and their interactions. This analyses yielded the expected four-way interaction between these factors, $F(1, 56) = 5.42$, $p < .05$, $\eta_p^2 = .09$, and no other effects in this analysis were reliable. To examine this interaction further we tested the object type by type of negative expression by restraint interactions within each type of negative expression condition separately.

In the fear condition the expected interaction between object type, facial expression and restraint emerged, $F(1, 28) = 4.19$, $p = .05$, $\eta_p^2 = .13$ (see Fig. 1). In order to examine this three-way interaction, we estimated the two-way interaction effect between object type and facial expression for participants with relatively low restraint scores (i.e., 1 SD below the mean standardized score of restraint) and for participants with relatively high restraint scores (i.e., 1 SD above the mean standardized score of restraint; see Aiken & West, 1991 for this method). Using this estimation procedure in the General Linear Model allows for a test of the 2 (object type) $\times$ 2 (cue type) within subjects design for low and high restrained participants separately without conducting a median split, while retaining all observations in the analyses. Moreover, with this estimation procedure we can test differences between mean reaction times to palatable food trials with emotional faces on the one hand and both types of control trials (i.e., palatable food trials with neutral faces and control trials with emotional faces) on the other hand within low versus high levels of restraint (see also Papies et al., 2007; Veling & Aarts, in press-b).

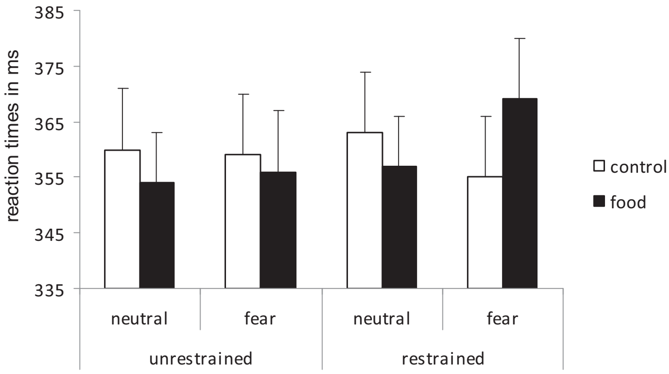

Fig. 1. Mean reaction times on action probe trials between food and control objects as a function of restrained eating and fearful and neutral facial expressions. Error bars = *SE*.

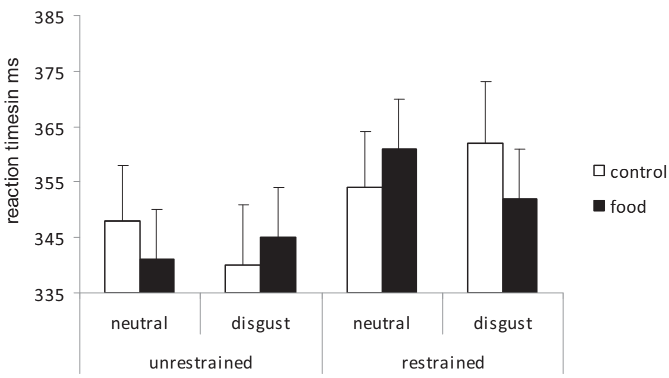

Fig. 2. Mean reaction times on action probe trials between food and control objects as a function of restrained eating and disgusted and neutral facial expressions. Error bars = *SE*.

Results in the fear condition showed that for relatively low restrained participants the interaction between object type and facial expression was unreliable, $F < 1$ (see left panel of Fig. 1). Importantly, and as expected, the interaction between object type and facial expression was reliable for relatively high restrained participants, $F(1, 28) = 11.76$, $p < .01$, $\eta_p^2 = .30$ (see right panel of Fig. 1). Analyses of the simple effects revealed that high restrained participants were slower to respond to the action probes when the action probes were preceded by palatable foods with a fearful facial expression compared to palatable foods with a neutral facial expression, $F(1, 28) = 4.54$, $p < .05$, $\eta_p^2 = .14$. In addition, participants were slower to respond after a palatable food with a fearful facial expression than a neutral object with a fearful facial expression, $F(1, 28) = 4.87$, $p < .05$, $\eta_p^2 = .15$. No other reliable effects were found in the fear condition.

Finally, we analyzed the results within the disgust condition. The pattern of results in the disgust condition is displayed in Fig. 2, and is quite different from the pattern in the fear condition. Furthermore, analyses within the disgust condition yielded no reliable effects (all *F*s < 3).

Discussion

We examined whether fear signals can inhibit unintentionally evoked motor impulses toward rewarding food objects. Consistent with our hypothesis, results revealed a slow-down in responses after perception of rewarding food objects together with fearful facial expressions, but only for restrained eaters. Because palatable foods have been found to be more rewarding and impulse-evoking for restrained eaters compared to unrestrained eaters (e.g., Brunstrom et al., 2004; Hofmann et al., 2010; Jansen & Van den Hout, 1991; Houben, Havermans, & Wiers, 2010; Houben, Roefs, et al., 2010; Papies & Hamstra, 2010), this finding suggests that that fear signals inhibited motor action only when the foods elicited strong impulses. This motor inhibition acted as a brake on subsequent action, and hence slowed-down subsequent responses. Thus, an emotional signal that is intrinsically related to motor inhibition, i.e., fear, appears effective in inhibiting impulses that are unintentionally evoked upon perception of rewarding foods.

Results further showed that faces displaying disgust did not lead to motor inhibition. This difference between facial expressions displaying disgust or fear supports our argument that the effect of fearful facial expressions is caused by motor inhibition processes rather than through the elicitation of negative affect per se (i.e., as fear has been related to motor inhibition and disgust not; e.g., Butler et al., 2007; Fanselow, 1994; Ferri et al., 2010; Oliveri et al., 2003). Thus, an emotional signal that is intrinsically related to motor inhibition appears effective in inhibiting impulses that are unintentionally evoked upon perception of rewarding food objects.

A number of theories of impulse control state that an important proximal cause of undesired impulsive behaviors toward rewarding objects is the unintentional preparation of action upon mere perception of these objects (e.g., Hofmann et al., 2008; Metcalfe & Mischel, 1999; Strack & Deutsch, 2004). This prepared action may guide overt behavior especially when conscious or intentional processes are unavailable (Baumeister & Heatherton, 1996; Hofmann et al., 2008). Indeed, recent work suggests that difficulty with inhibiting prepared responses toward rewarding foods predicts weight gain (e.g., Batterink, Yokum, & Stice, 2010; Nederkoorn et al., 2010). Despite this growing consensus there has been only limited attention to the question of how such unintentional motor impulses to rewarding food objects can be directly inhibited (e.g., Guerrieiri, Nederkoorn, Schrooten, Martijn, & Jansen, 2009; Houben & Jansen, 2011; Veling & Aarts, in press-a), and no work has been conducted to examine how inhibition may be accomplished by the environment through presentation of intrinsic inhibitory signals. The present results thus provide new insight by showing that fear signals can be used to inhibit unintentionally prepared motor responses. Because unintentional action preparation is often assumed to be a proximal cause of impulsive behavior (e.g., Hofmann et al., 2008; Metcalfe & Mischel, 1999; Strack & Deutsch, 2004), the present research provides further support for an alternative approach to improving impulse control. Thus, inhibiting unintentional action preparation upon perception of rewarding objects (Hofmann et al., 2008; Veling & Aarts, in press-a) may improve impulse control and might complement the more common approaches that focus on reflective determinants of behavior (e.g., changing healthy intentions; Webb & Sheeran, 2006).

Because the present work examined effects of fear signals on immediate responses, it remains to be tested whether fear signals are effective in reducing overt impulsive behavior toward palatable foods (such as actual food intake). Importantly, recent work showing that associating palatable foods with experimentally created stop signals (i.e., no-go cues in a go/no-go task) can reduce subsequent food intake particularly when these foods are highly rewarding and impulse-evoking (i.e., for restrained eaters; Houben & Jansen, 2011) suggests that this is a genuine possibility. A potential advantage of intrinsic stop signals, such as fear signals, over experimentally created stop signals (e.g., no-go cues in a go/no-go task) is that intrinsic signals can be presented in the vicinity of rewarding impulse-evoking food without prior training. Future work is needed, however, to test whether such an intervention is effective in reducing overt impulsive behavior, such as food intake, of palatable foods.

A striking consistency between the current research and that of Houben and Jansen (2011) is that in both studies the effects of stop signals were only found for restrained eaters. In the present research we expected an effect for restrained eaters only, because, all else being equal, palatable foods are more rewarding and impulse-evoking for restrained compared to unrestrained eaters (e.g., Brunstrom et al., 2004; Hofmann et al., 2010; Houben, Havermans, et al., 2010; Houben, Roefs, et al., 2010; Jansen & Van den Hout, 1991; Papies & Hamstra, 2010). This does not mean, however, that stop signals cannot inhibit impulses for unrestrained eaters. For instance, in previous work we have shown that stop signals can inhibit motor impulses to objects that are rewarding because they satisfy basic needs (i.e., a soda for relatively thirsty participants; Veling & Aarts, 2009; Veling & Aarts, in press-b). Hence, it may very well be that stop signals can also be effective to inhibit motor impulses to foods for unrestrained eaters when these foods elicit very strong impulses (e.g., under conditions of food deprivation). However, without taking situational factors into account, stop signals appear most effective for those people that have the greatest difficulty with controlling their impulses (i.e., restrained eaters).

Finally, with regard to the differential effects of fear and disgust, it is important to emphasize that the present research focused on immediate effects of these emotional signals on the motor system. Hence, the present research does not suggest that signals of disgust may not alter responses toward food. For instance, research has shown that participants indicate less desire to eat foods when they observe another person consuming these foods with a disgusted facial expression (Barthomeuf et al., 2009). However, unlike fear signals, disgust signals are not related to motor inhibition. Consistent with this argument, the present research shows that when it comes to unintentionally evoked action upon mere perception of rewarding impulse-evoking foods, fear signals inhibit this action immediately whereas disgust signals do not. It could be that different kinds of negative emotional signals (e.g., disgust and fear) can reduce the reward value of objects when these signals are repeatedly and consistently presented near these objects (e.g., Aarts, Custers, & Holland, 2007; Aarts et al., 2010; Houben, Havermans, et al., 2010). In the long run, such decreases in evaluation are likely to reduce impulsive behavior toward (previously) rewarding foods (e.g., Hofmann et al., 2008). However, only fear signals inhibit motor impulses to act on the objects even *before* such negative associations are established. This reasoning suggests that fear signals may be particularly useful as a tool to reduce impulsive behavior toward rewarding foods when training or conditioning procedures to reduce the impulse-evoking quality of rewarding foods are difficult or impossible to implement, and when behavior is strongly guided by impulses that are unintentionally elicited upon perception of the rewarding foods.

In sum, we observed that unintentional motor impulses evoked by rewarding food objects are inhibited when these objects are presented with a fear signal. As such we have identified a way to inhibit a proximal cause of impulsive behavior. Considering that overconsumption of palatable foods poses a great individual and societal health problem (e.g., WHO, 2000), studying effects of presenting fear signals near palatable foods may provide new insights in how the environment can facilitate control over impulsive responses toward and intake of such unhealthy foods.

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