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How Does Not Responding to Appetitive Stimuli Cause Devaluation: Evaluative Conditioning or Response Inhibition?

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In a series of 6 experiments (5 preregistered), we examined how not responding to appetitive stimuli causes devaluation. To examine this question, a go/no-go task was employed in which appetitive stimuli were consistently associated with cues to respond (go stimuli), or with cues to not respond (either no-go cues or the absence of cues; no-go stimuli). Change in evaluations of no-go stimuli was compared to change in evaluations of both go stimuli and of stimuli not presented in the task (untrained stimuli). Experiments 1 to 3 show that not responding to appetitive stimuli in a go/no-go task causes devaluation of these stimuli regardless of the presence of an explicit no-go cue. Experiments 4a and 4b show that the devaluation effect of appetitive stimuli is contingent on the percentage of no-go trials; devaluation appears when no-go trials are rare, but disappears when no-go trials are frequent. Experiment 5 shows that simply observing the go/no-go task does not lead to devaluation. Experiment 6 shows that not responding to neutral stimuli does not cause devaluation. Together, these results suggest that devaluation of appetitive stimuli by not responding to them is the result of response inhibition. By employing both go stimuli and untrained stimuli as baselines, alternative explanations are ruled out, and apparent inconsistencies in the literature are resolved. These experiments provide new theoretical insight into the relation between not responding and evaluation, and can be applied to design motor response training procedures aimed at changing people's behavior toward appetitive stimuli.

Keywords: devaluation, evaluation, food, go/no-go training, response inhibition

Evaluations of the everyday objects in our environment are an important determinant of our behavior toward them. Evaluations may automatically trigger behavioral tendencies (Strack & Deutsch, 2004), or influence our intentions or deliberate decisions, which in turn guide behavior (Ajzen, 1991, 2012; Strack & Deutsch, 2004). Hence, the question of how evaluations of objects can be influenced is a central theme in psychology (e.g., Gawronski & Bodenhausen, 2006; Olson & Zanna, 1993; Zajonc, 1968). Interestingly, the idea that evaluations steer behavior has recently been proposed as a possible means to reduce health-harming behaviors that appear to result from the overvaluation of certain appetitive stimuli. For instance, the overvaluation of alcohol and high-calorie foods can lead to health-harming behaviors like binge drinking and unhealthy eating (Stice, Spoor, Bohon, Veldhuizen, & Small, 2008; Wrase et al., 2007) and lowering the evaluations of such stimuli has been shown to change overt behavior toward them (Hollands, Prestwich, & Marteau, 2011; Houben, Havermans, & Wiers, 2010).

One way of devaluing appetitive stimuli is via response inhibition training (e.g., Houben, Nederkoorn, Wiers, & Jansen, 2011; Lawrence et al., 2015; Veling, Holland, & van Knippenberg, 2008). Until now, two response inhibition tasks have been used, namely the go/no-go task (Donders, 1868/1969) and the stop-signal task (Logan, Cowan, & Davis, 1984). Both the go/no-go task (GNG) and the stop-signal task (SST) consist of two types of trials: go trials in which people make a motor response (e.g., press a key), and no-go trials (or stop trials) in which people do not respond (e.g., do not press any key). When used as training, appetitive stimuli can be consistently presented on no-go trials so that participants do not respond to them. Brief training with GNG or SST has been shown to lower the evaluations of a variety of stimuli, such as high calorie food stimuli (Veling, Aarts, & Stroebe, 2013a), alcoholic drinks (Houben et al., 2011; Houben, Havermans, Nederkoorn, & Jansen, 2012), faces (Doallo et al., 2012; Kiss, Raymond, Westoby, Nobre, & Eimer, 2008), sexual pictures (Ferrey, Frischen, & Fenske, 2012), and geometric shapes that are associated with monetary values (Wessel, O'Doherty, Berkebile, Linderman, & Aron, 2014). The effect of training is not limited to evaluations; GNG and SST can influence food choice (Veling et al., 2013a; Veling, Aarts, & Stroebe, 2013b), reduce the consumption of palatable food (Houben, 2011; Houben & Jansen, 2011; Houben & Jansen, 2015; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015; Veling, Aarts, & Papies, 2011), and reduce drinking of alcoholic beverages (Houben et al., 2011, 2012; Jones & Field, 2013). Repeated training with high-calorie food stimuli has also been shown to facilitate weight loss in two studies (Lawrence, O'Sullivan, et al., 2015; Veling, van Koningsbruggen,

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Aarts, & Stroebe, 2014). These findings suggest that not responding to appetitive stimuli can lead to their devaluation, which can be used to develop behavioral change interventions.

One interesting aspect of using response inhibition training to devalue appetitive stimuli is that the devaluation effect appears to be stronger for stimuli that are perceived to be more appetitive (Veling et al., 2008, 2013b). This seems different from devaluation effects that can be induced by another prominent method to influence stimulus evaluations, evaluative conditioning, which tends to have particularly strong effects on changing evaluations of neutral stimuli (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). Therefore, response inhibition training may be especially suited for reducing health-harming behaviors that are triggered by the overvaluation of appetitive stimuli (for a recent meta-analysis of the effect of such trainings on health outcomes, see Allom, Mullan, & Hagger, 2015).

Devaluation effects induced by response inhibition training are generally assumed to be caused by response inhibition. In line with this claim, previous neurocognitive studies have found activation of the right inferior frontal cortex (rIFC), a brain area underlying response inhibition, when participants did not respond in a go/no-go task (e.g., Berkman, Burklund, & Lieberman, 2009; Konishi, Nakajima, Uchida, Sekihara, & Miyashita, 1998; Konishi et al., 1999; for reviews, see Aron, Robbins, & Poldrack, 2004, 2014). Another study suggests response inhibition toward affective images is accompanied by a dampened affective response in the amygdala (Berkman et al., 2009). Moreover, in an ERP-study the strength of emotional devaluation of faces by response inhibition correlated with the no-go N2 component, an index of the efficiency of response inhibition (Kiss et al., 2008). Combined, these results suggest that not responding in GNG or SST may activate an inhibition process, which may be associated with attenuated evaluations. By repeatedly inhibiting one's response toward an appetitive stimulus, an inhibitory 'tag' may be associated with the stimulus (Verbruggen & Logan, 2008), leading to decreased evaluation when the stimulus is subsequently encountered. The Behavior Stimulus Interaction theory (BSI theory, Veling et al., 2008) more specifically predicts that response inhibition only leads to devaluation of appetitive stimuli. According to the BSI theory, appetitive or rewarding stimuli trigger an approach tendency, which needs to be inhibited when the stimuli are paired with a no-go cue. To prevent continuous oscillation between the approach tendency and inhibiting this tendency, the evaluation of these appetitive stimuli is decreased to facilitate subsequent courses of action. The BSI theory therefore predicts that devaluation via response inhibition specifically serves to dampen the approach tendency toward appetitive stimuli.

Alternative Explanations From Evaluative Conditioning

Although the evidence reviewed above is in line with the *response inhibition account*, alternative explanations could be raised from the perspective of evaluative conditioning (EC). In studies on EC, the evaluation of a stimulus can be changed by presenting it in close temporal or spatial proximity with another stimulus. The first stimulus is often referred to as *conditioned stimulus* (CS), and the second stimulus as *unconditioned stimulus* (US). A large number of studies have shown that by pairing CS with an either positive or negative US, the evaluation of CS changes in the direction of the US. That is, the evaluation of CS becomes more positive after being paired with a positive US, and becomes more negative after being paired with a negative US. This transfer of valence is referred to as the EC effect (for a recent meta-analysis, see Hofmann et al., 2010). In addition to this general finding, previous research has shown that pairing appetitive (food) stimuli with negative US's also leads to devaluation of these stimuli (Hollands et al., 2011). To the extent that no-go cues or not responding can be considered as negative US's, EC accounts can explain the devaluation effects observed after response inhibition training.

First, devaluation may be caused by associations between appetitive stimuli and the no-go cue. Although there is no direct evidence showing that no-go cues are negatively evaluated, there is research showing that words related to inaction (e.g., 'stop') are evaluated more negatively than words related to action (e.g., 'go'; McCulloch, Li, Hong, & Albarracin, 2012). Therefore, by labeling a certain cue as a stop or no-go cue, this specific cue may acquire a negative connotation. By repeatedly pairing appetitive stimuli with a negative cue, the evaluations of these stimuli may decrease through this association with the cue rather than due to response inhibition. We term this account the *no-go cue EC account*.

A second EC account for devaluation can be that not responding, but not the no-go cues per se, is perceived to be negative. For instance, the evaluative response coding view (Eder & Rothermund, 2008) proposes that evaluative codes are part of the representation of behavioral responses. Not responding may be coded as negative, for instance, via the instruction of 'do not respond' or 'stop responding' (McCulloch et al., 2012). Furthermore, recent research on the interaction effects between valence and action shows an inherent coupling between no-go responses and punishment, suggesting that not responding in itself may be linked to punishment (Guitart-Masip et al., 2012; Guitart-Masip, Duzel, Dolan, & Dayan, 2014). During the training, the negativity of not responding may then be associated with appetitive stimuli in an EC-like mechanism. We term this account the *nonresponse EC account*.

Although GNG and SST are often referred to as response inhibition training, previous studies cannot disentangle these three accounts (i.e., the response inhibition account, the no-go cue EC account and the nonresponse EC account) because of the consistent mappings between appetitive stimuli, no-go cues and not responding. Knowing which of these accounts is the underlying mechanism of devaluation is not only theoretically relevant, but also practically important. Different implications can be drawn from these three accounts for an effective training procedure. For instance, according to the no-go cue EC account, the no-go cue is an indispensable component to create devaluation, whereas according to the other two accounts it can be omitted. Furthermore, although according to the nonresponse EC account, the percentage of no-go trials would not influence the devaluation effect, the inhibition account predicts that including many no-go trials in the go/no-go task (thereby reducing the recruitment of inhibition on no-go trials, Bruin & Wijers, 2002; Nakata et al., 2005) would lead to weaker devaluation. Based on these different predictions, in the current research we systematically vary the presence of no-go cues and the trial percentages, to test these three different accounts and gain more insight into the underlying mechanism of the devaluation effect.

The Current Research

Considering the applied value of food-related response inhibition training, we use pictures of food as stimuli in the current research. As reported by the World Health Organization, one main cause of the worldwide obesity epidemic is the overconsumption of high-calorie food (World Health Organization, 2015), and food-related response inhibition training may have the potential to change people's eating behaviors and facilitate weight loss (Lawrence, O'Sullivan, et al., 2015; Veling et al., 2014). We only use GNG, because GNG appears to yield stronger training effects on health behavior than SST (Allom et al., 2015; Jones et al., 2016) and because we specifically test the role of no-go cues by removing them on some trials. This cannot be achieved with SST, as SST includes only no-go or stop cues.

In the first part (Experiments 1 to 3), we test whether devaluation of appetitive food stimuli on no-go trials is caused by the presence of no-go cues. Specifically, we test the no-go cue EC account by manipulating the presence of no-go cues independently of whether participants respond or not. If the devaluation effect is stronger with no-go cues, at least part of the effect can be attributed to EC by no-go cues. However, if the presence of no-go cues does not influence the effect, this no-go cue EC account can be ruled out.

In the second part (Experiments 4 to 6), and to pit the nonresponse EC account and the response inhibition account against each other, we first change the percentage of no-go trials from 25% (Experiment 4a) to 75% (Experiment 4b). The nonresponse EC account predicts devaluation of no-go stimuli in both experiments. In contrast, the response inhibition account predicts weaker or no devaluation in the 75% no-go version, because the inclusion of many no-go trials weakens the engagement of inhibition on no-go trials (Bruin & Wijers, 2002; Nakata et al., 2005). In Experiment 5 we instruct participants to observe the 25% no-go training instead of performing the training. The nonresponse EC account predicts devaluation of both go and no-go stimuli in this experiment, whereas the response inhibition account predicts no effect. In Experiment 6 we again use the 25% no-go version, but in the training we present food stimuli that are relatively neutral instead of attractive to explore whether not responding to relatively neutral stimuli also leads to devaluation.

Definition of the Devaluation Effect

We adopt a strict definition for devaluation in the current research. Most previous studies with response inhibition training have compared no-go stimuli to either go stimuli or stimuli that were not used in the training (hereafter untrained stimuli; but see Veling et al., 2008). Although two baselines have been used in the research area of distractor devaluation (see Fenske & Raymond, 2006), previous research on devaluation induced by response inhibition failed to use these two baselines consistently. Using only one of the baselines is not sufficient to show devaluation from the training. For instance, if the evaluation of no-go stimuli is lower than that of go stimuli but not than untrained stimuli, this could be due to increased evaluation of go stimuli (for a potential valuation effect of go stimuli, see Schonberg et al., 2014). If the evaluation of no-go stimuli is lower than untrained stimuli but not go stimuli, the devaluation is not specific to no-go stimuli, but may be attributable to general characteristics of the training, for instance its tediousness. Only when the evaluation of no-go stimuli is lower than *both* go and untrained stimuli, will we accept the effect as a devaluation effect.[1]

Preregistrations

For the sake of transparency and to be able to distinguish between confirmatory and exploratory analyses, we preregistered the planned sample sizes, analyses plans and expected results (except for Experiment 1). For an overview of the preregistrations, see the link to the project on Open Science Framework.[2] This overview also specifies when we deviated from the original preregistrations (e.g., one or two baselines, see Footnote 1; the exclusion criteria), and whether these changes influenced the results.

Experiment 1

The purpose of Experiment 1 was twofold. First, we tested whether devaluation could be observed when using both go and untrained stimuli as baselines. Second, we compared nonresponse trials in which the no-go cue was provided (hereafter no-go trials) with nonresponse trials in which the no-go cue was not provided (hereafter no-cue trials). Behaviorally the no-go and no-cue trials were identical: participants did not respond. The only difference was whether the no-go cue was provided. By directly comparing no-go and no-cue trials, we aim to test whether the devaluation effect would be influenced by the no-go cue.

Method

Sample size. Based on a meta-analysis by the time of conducting this experiment, the average effect size of GNG on health outcomes is Cohen's $d^+ = 0.534$, 95% CI [0.327, 0.741] (Allom, 2014). Power analysis indicated that 30 participants would be needed to achieve 80% power (G*Power; Faul, Erdfelder, Buchner, & Lang, 2009). In Experiments 1 to 3, our planned sample size was between 40 and 50, which exceeded the required sample size.

Participants. Forty-five participants took part in the experiment for course credits or monetary compensation. Different samples were used for all the experiments. Four participants were excluded because their accuracy on go, no-go, or no-cue trials in GNG was 3 *SD* below the mean. Forty-one participants remained in the final sample (7 males, 34 females, $M_{age} = 21.7$ years, $SD_{age} = 3.2$). Exclusion of participants did not change the results.

Materials. Eighty pictures of various palatable foods (e.g., desserts, full meals, fruits, vegetables, candies etc.) were selected from the food-pics database (Blechert, Meule, Busch, & Ohla,

[1] In the preregistrations of Experiments 3, 4a, 4b, and 5, only the untrained stimuli were registered as the baseline. However, as explained in the main text, using only untrained stimuli as the baseline does not rule out task tediousness as an alternative explanation. We therefore decided to be more conservative than the preregistrations by consistently adopting two baselines. In addition, although evaluations of go stimuli were not explicitly specified in some of our preregistrations as a baseline, previous research has always compared no-go stimuli to go stimuli and used the difference as the evidence for the devaluation effect. The difference between no-go and go stimuli could be expected based on previous research (e.g., Veling et al., 2008, 2011, 2013a, 2013b).

[2] For an overview of the preregistrations, experimental materials, data files and supplementary material. (see https://osf.io/9dxwa/).

2014). The procedure was implemented in PsychoPy (version v1.81.03; Peirce, 2007) and run on a Windows 7 computer individually for each participant.

Procedure.

Preparation. Participants were asked to refrain from eating for at least 4 hours before the experiment. Experiments 1 to 3 were conducted after another food-related training experiment.[3]

Pretraining evaluation. Participants first received a self-paced evaluation task in which they indicated how attractive they found each of the 80 foods by using a 200-point slider (−100 = *not at all*, 100 = *very much*, the cursor always started at 0). The order of pictures was randomized (see Figure 1).

Sorting and selection. The 80 food pictures were ranked from the highest evaluation to the lowest. Since we were mainly interested in decreasing the evaluations of highly appetitive stimuli (but see Experiment 6), the 50 pictures with the highest evaluations were selected for GNG. The selected pictures were further divided into 5 sets, with 10 pictures in each set. The average evaluations from each set were matched. For the pretraining evaluations of food in all training conditions, see Table 1.

Go/No-Go training. After the selection procedure, participants received GNG. We randomly assigned 2 sets of pictures to the go trials (i.e., 20 pictures), 1 set to the no-go trials (i.e., 10 pictures), and 1 set to the no-cue trials (i.e., 10 pictures). The remaining set (i.e., 10 pictures) was not used in GNG and served as untrained baseline.

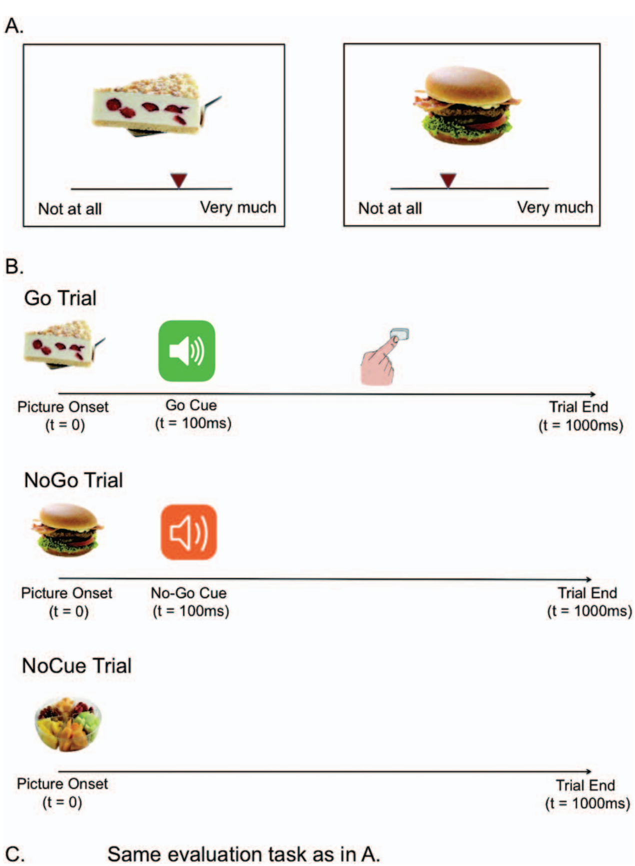

Figure 1. Diagram of general experimental procedure. (A) Pretraining evaluation. (B) Go/No-Go training. (C) Posttraining evaluation. See the online article for the color version of this figure.

Each trial in GNG started with the presentation of a picture in the middle of the screen. If the picture was assigned to the go trial, 100 ms after picture onset a tone was played via a headphone, and participants were instructed to press the B key on the keyboard as fast as possible before the picture disappeared. If the picture was assigned to the no-go trial, a different tone was played 100 ms after picture onset, and participants were asked to not press any key until the picture disappeared by itself. Finally, if the picture was assigned to the no-cue trial, no tone was played, and participants also did not need to respond. The two tones used as go and no-go cues were counterbalanced across participants (frequencies: 400 and 1000 Hz, duration: 300 ms). In all trials, the picture remained on screen for 1 second. The intertrial interval randomly varied from 1.5 to 2.5 seconds, in steps of 100 ms.

Before the experimental blocks, participants received a practice block of 16 trials. The 50 selected pictures were not used in practice. During practice, participants received an error message if they made incorrect responses on go or no-go trials. No performance feedback was provided for the experimental blocks. In each experimental block, each of the 40 selected pictures was randomly presented once, and the whole training consisted of 5 blocks, resulting in 200 trials in total.

Posttraining evaluation. After GNG, participants received a same evaluation task as before GNG. Only the 50 selected pictures were presented.

Questionnaires and demographics. In the end, participants filled out the restraint eating scale (Herman & Polivy, 1980), reported whether they were currently on a diet, the last time they consumed food, their current hunger level, weight, height, and for exploratory reasons one open-ended question on their broad ideas about the aim of the study. Participants who explicitly stated that not responding to stimuli made them appear less attractive were excluded (one participant in Experiments 4a, 4b, and 6, respectively).

Results

Main analyses were conducted in SPSS 23. For a summary of participants' performance in GNG, see Table 2. Because of the overall high accuracies, food stimuli associated with occasional incorrect responses were not excluded from the analyses on stimulus evaluations. For responses on questionnaires and demographics, see the supplementary material in the link from Footnote 2.

[3] Participants first finished the cue-approach training (CAT, see Schonberg et al., 2014), which took around one hour. After finishing CAT, they had a 5-min break to consume one or two snacks or fruits. The current research started after the break. Although Experiments 1 through 3 were preceded by CAT, we think the data are unlikely to be influenced by CAT, because (a) different stimulus materials were used in CAT and Experiments 1 through 3, (b) there were at least 20 min between the CAT training and the go/no-go training, (c) the between-subjects manipulation in the CAT experiments does not moderate the reported effects, (d) the obtained effect sizes for stimulus devaluation in the present experiments are very close to the effect sizes from similar research as reported in three recent meta-analyses (Allom et al., 2015; Jones et al., 2016; Turton, Bruidegom, Cardi, Hirsch, & Treasure, 2016), and (e) there is no reason to suspect CAT would influence the critical within-subject comparison between the no-go and no-cue training conditions in Experiments 1 and 2.

Table 1
Evaluations Before Go/No-Go Training in Experiments 1 to 6

Experiment	Untrained	Go	No-Go	No-Cue	*F* value	*p* value
1	40.70 (3.00)	40.83 (2.99)	40.64 (2.97)	41.12 (3.05)	$F(3, 120) = 1.62$	$p = .188$
2	43.78 (3.20)	43.29 (3.18)	43.31 (3.23)	43.52 (3.20)	$F(3, 111) = 3.06$	$p = .031$
3	36.28 (3.00)	36.51 (2.99)	—	36.58 (2.96)	$F(2, 84) = 1.31$	$p = .277$
4a	54.97 (2.53)	55.01 (2.48)	55.17 (2.52)	—	$F(2, 52) = .84$	$p = .436$
4b	46.73 (2.82)	46.67 (2.87)	46.91 (2.82)	—	$F(2, 56) = 1.05$	$p = .355$
5	54.61 (2.85)	54.53 (2.82)	54.46 (2.81)	—	$F(2, 56) = .36$	$p = .699$
6	−7.06 (3.35)	−6.99 (3.41)	−7.13 (3.39)	—	$F(2, 76) = .08$	$p = .923$

Note. Cells with a line were not included in the experiment. Standard errors are between parentheses.

For each food training condition (i.e., go, no-go, no-cue and untrained), we first calculated the average evaluation for both pre- and post-training. A difference score was then calculated by subtracting the pretraining evaluation from the posttraining evaluation (i.e., difference score = posttraining evaluation − pretraining evaluation). A negative difference score indicates participants found the food less attractive after GNG. The difference scores for the four training conditions were: untrained, $M = -6.20$, $SD = 8.87$; go, $M = -7.70$, $SD = 10.03$; no-go, $M = -11.68$, $SD = 9.87$; no-cue, $M = -12.31$, $SD = 10.67$. For all training conditions, the difference score was negative, indicating a general decrease in evaluation. This general decrease is likely attributable to regression to the mean and is not of main interest here.

To test whether the decrease in liking differed for different training conditions, we first ran a repeated-measures ANOVA with training condition as the within-subject factor and the difference score as the dependent variable. The main effect of training condition was significant, $F(3, 120) = 7.42$, $p < .001$, $\eta^2 = .156$ (see Figure 2). Note that the main effect of training condition on the difference scores is equivalent to the interaction effect between measurement time (pre- vs. post-training) and training condition on the average evaluations, and we report the analyses on the difference scores so that we do not need to break down the interaction effect for each ANOVA.

Next, we compared no-go foods with untrained and go foods respectively using paired-samples *t* tests. Additional analyses were performed and reported in footnotes if the assumption of normal distribution was not met. Results from paired-samples *t* tests showed the difference score of no-go foods was significantly lower than that of untrained foods, $M = -5.48$, $SE = 1.59$, $t(40) = -3.45$, $p = .001$, Cohen's $d_{unb} = -0.573$, 95% CI [−0.936, −0.225],[4] and also significantly lower than that of go foods, $M = -3.98$, $SE = 1.52$, $t(40) = -2.61$, $p = .013$, $d_{unb} = -0.392$, 95% CI [−0.710, −0.085], suggesting evaluations of no-go foods decreased more through training. This larger decrease for no-go foods in comparison to both go and untrained foods is thus evidence for devaluation. The difference score of no-cue foods was also significantly lower than untrained foods, $M = -6.11$, $SE = 1.77$, $t(40) = -3.46$, $p = .001$, $d_{unb} = -0.611$, 95% CI [−0.997, −0.241], and go foods, $M = -4.61$, $SE = 1.62$, $t(40) = -2.85$, $p = .007$, $d_{unb} = -0.437$, 95% CI [−0.763, −0.122], indicating a devaluation effect for no-cue foods as well.[5] The difference between no-go and no-cue foods was not significant, $M = -0.63$, $SE = 1.43$, $t(40) = -0.44$, $p = .661$, $d_{unb} = -0.060$, 95% CI [−0.333, 0.211].

To explore whether responding to go foods increased their evaluations, we also directly compared go foods with untrained foods. The difference was not statistically significant, $M = -1.50$, $SE = 1.35$, $t(40) = -1.11$, $p = .274$, $d_{unb} = -0.155$, 95% CI [−0.440, 0.125].

Because of the difficulty of interpreting null-findings with conventional analyses, the nonsignificant differences were also tested using Bayesian analyses (JASP, Version 0.7.1.12, Love et al., 2015; Cauchy prior width = 0.707). A Bayesian paired-samples *t* test between no-go and no-cue foods gave a Bayes factor (BF) of 0.185, supporting the null hypothesis that no difference occurred between no-go and no-cue stimuli (a BF below 1/3 is considered substantial evidence for the null hypothesis, see Dienes, 2014). BF for the comparison between go and untrained stimuli was 0.299, which also supported the conclusion that responding to go stimuli did not make them more attractive.

Table 2
Performance in Go/No-Go Training in Experiments 1 to 4 and 6

Experiment	No-Go accuracy	No-Cue accuracy	Go accuracy	Go RT (ms)
1	92.5% (.8%)	99.8% (.1%)	99.1% (.2%)	437.4 (7.8)
2	87.6% (1.4%)	98.3% (.4%)	73.7% (.2%)	278.2 (10.2)
3	—	97.8% (.3%)	99.2% (.4%)	355.7 (7.2)
4a	95.8% (.8%)	—	99.7% (.1%)	423.4 (13.1)
4b	99.1% (.2%)	—	99.4% (.3%)	433.2 (8.7)
6	93.5% (.8%)	—	99.1% (.2%)	439.3 (9.2)

Note. Cells with a line were not included in the experiment. Standard errors are between parentheses.

[4] Following the recommendations by Cumming (2012) and Lakens (2013), we use the average standard deviation of both repeated measures as the standardizer for calculating Cohen's *d,* and then apply Hedges' correction to get an unbiased estimation Cohen's d_{unb} (equivalent to Hedges' g_{av} in Lakens, 2013). The calculation of Cohen's d_{unb} and the CI on *d* was carried out in ESCI (Cumming, 2012).

[5] The difference between no-cue and untrained stimuli and the difference between no-cue and go stimuli were not normally distributed. After we deleted 7 participants whose difference score was 1.5 *SD* away from the mean, the normality assumption was met. This subsample lead to same result, $M_{nocue—untrained} = -3.47$, $SE = 1.14$, $t(33) = -3.05$, $p = .005$, $d_{unb} = -0.445$, 95% CI [−0.765, −0.139]; $M_{nocue\text{-}go} = -4.23$, $SE = 1.07$, $t(33) = -3.95$, $p < .001$, $d_{unb} = -0.540$, 95% CI [−0.853, −0.245]. For the sake of consistency in the main text we reported the results based on the 41 participants in the final sample.

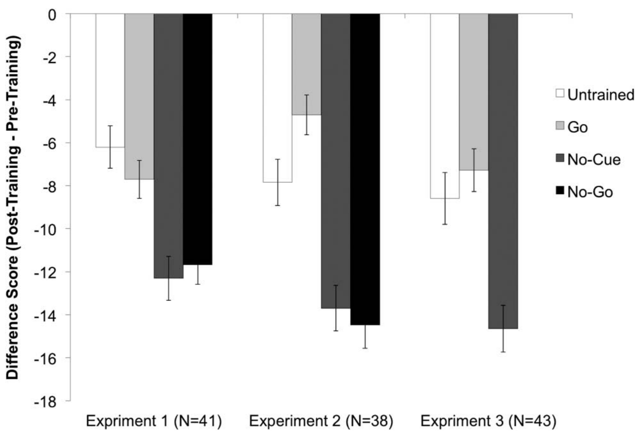

Figure 2. Difference scores (posttraining–pretraining evaluation) for different food training conditions in Experiments 1 to 3. Error bars stand for within-subject standard errors.

Discussion

In this first experiment, we showed that appetitive foods were devalued after being presented on no-go trials. This result replicated previous findings but also served as a stronger demonstration of the devaluation effect since we adopted both untrained and go foods as baselines (cf. Veling et al., 2013a, 2013b). Crucially, a similar devaluation effect was observed for no-cue foods, and no difference was observed between no-go and no-cue stimuli, indicating that no-go cue does not contribute to devaluation.

One potential limitation of the current experiment is that although the explicit no-go cue was not provided on no-cue trials, participants may still have perceived an 'implicit' no-go cue. Because the go and no-go cues were always presented 100 ms after picture onset, participants may have learned that if no tone was played after 100 ms, the current trial must be a no-cue trial and they should not respond. The absence of cues may therefore have become an 'implicit' no-go cue. Perceiving such an 'implicit' no-go cue on no-cue trials may have then led to devaluation. We carried out Experiment 2 to test this hypothesis of 'implicit' no-go cue.

Experiment 2

Experiment 2 used the same procedure from Experiment 1 with the following changes. To make the 'implicit' no-go cue less clear, we delayed the presentation of go cue and dynamically varied the delay using a staircase procedure (see Method section below). The rationale is that in this case if participants did not hear any cue after 100 ms, this did not mean that the current trial must be a no-cue trial; the go cue could still be played later. This way, the absence of a cue may not serve as a clear 'implicit' no-go cue. If in this case the no-cue foods were not devalued, this would support the 'implicit' no-go cue hypothesis; however, if we still found a devaluation effect, the 'implicit' no-go cue hypothesis would be less plausible.

Method

Participants. Forty participants participated in the experiment. Two participants were excluded because of low accuracies on no-go or no-cue trials (3 *SD* below the mean; Not preregistered; exclusion of participants did not change the results). Because we used a staircase procedure that predetermined the go accuracy to be around 75%, go accuracies were not used as an exclusion criterion. The final sample consisted of 38 participants (8 males, 30 females, $M_{age} = 22.6$ years, $SD_{age} = 2.90$).

Materials and procedure. The same procedure from Experiment 1 was used. For GNG, we presented 20 pictures on go trials, 10 pictures on no-go trials, 10 pictures on no-cue trials, and the remaining 10 as untrained foods. The only difference was that we implemented a staircase procedure on go trials. The go cue was played after a delay from picture onset on go trials. This delay was initiated at 650 ms and dynamically adjusted. If participants responded in time, the delay increased by 17 ms; if they failed, the delay decreased by 50 ms. This procedure ensured that the accuracy on go trials would be around 75%. More importantly, this procedure made the occurrence of go cues less predictable. The no-go cue was still presented 100 ms after picture onset.

Results

To check the staircase procedure, we calculated the go accuracy and average go cue delay for each participant. The average go accuracy across participants was 73.7%, $SD = 1.4\%$, which was close to the predetermined 75%. The average go cue delay was 600 ms ($SD = 65.8$), indicating that on average the go cue was played 600 ms after picture onset, which was much later than the no-go cue. Because the presentation of go cues was delayed and varied, the absence of cues at 100 ms after picture onset could not serve as a clear 'implicit' no-go cue.

The main effect of food training condition from repeated-measures ANOVA was significant, $F(3, 111) = 15.41$, $p < .001$, $\eta^2 = .294$ (see Figure 2). The difference scores were: untrained, $M = -7.85$, $SD = 10.20$; go, $M = -4.70$, $SD = 9.47$; no-go, $M = -14.47$, $SD = 11.36$; no-cue, $M = -13.69$, $SD = 12.31$. Paired-samples *t* tests showed that the difference score of no-go foods was significantly lower than untrained foods, $M = -6.62$, $SE = 1.86$, $t(37) = -3.57$, $p = .001$, $d_{unb} = -0.601$, 95% CI [−0.975, −0.245], and go foods, $M = -9.77$, $SE = 1.68$, $t(37) = -5.82$, $p < .001$, $d_{unb} = -0.915$, 95% CI [−1.309, −0.550], replicating the devaluation effect. Similar results were found for no-cue foods: the difference score of no-cue foods was lower than untrained foods, $M = -5.85$, $SE = 1.80$, $t(37) = -3.25$, $p = .002$, $d_{unb} = -0.507$, 95% CI [−0.848, −0.181], and go foods, $M = -8.99$, $SE = 1.65$, $t(37) = -5.46$, $p < .001$, $d_{unb} = -0.802$, 95% CI [−1.163, −0.467]. Direct comparison between no-go and no-cue foods revealed no significant difference, $M = -0.78$, $SE = 1.62$, $t(37) = -0.47$, $p = .643$, $d_{unb} = -0.064$, 95% CI [−0.341, 0.210], BF = 0.193.

Direct comparison between go and untrained foods showed that the difference score of go foods was higher than that of untrained foods, $M = 3.14$, $SE = 1.48$, $t(37) = 2.12$, $p = .041$, $d_{unb} = 0.313$, 95% CI [0.013, 0.622]. This smaller decrease in liking for go foods reflects a potential valuation effect. This finding is in line with the valuation effect of go stimuli from recent research that also employed a staircase procedure on go trials (Schonberg et al., 2014).

Discussion

In this experiment, we employed the staircase procedure on go trials to test the "implicit" no-go cue hypothesis. Although the absence of cues could still serve as an "implicit" no-go cue after around 600 ms (i.e., the average go cue delay), this 'implicit' no-go cue was rendered far less clear than in Experiment 1. The devaluation effect was again replicated for both no-go and no-cue foods, suggesting that the devaluation effect for no-cue foods cannot be fully explained by perceiving an 'implicit' no-go cue. More importantly, the direct comparison between the no-go and no-cue foods showed no difference, suggesting that presenting an explicit no-go cue does not contribute to the devaluation effect.

In Experiments 1 and 2 (see Table 2), participants were more accurate on no-cue trials than on no-go trials (Experiment 1, no-cue $M = 99.8\%$, $SD = 0.6\%$, no-go $M = 92.5\%$, $SD = 5.2\%$, $t(40) = 9.17$, $p < .001$; Experiment 2, no-cue $M = 98.3\%$, $SD = 2.3\%$, no-go $M = 87.6\%$, $SD = 8.7\%$, $t(37) = 6.73$, $p < .001$), whereas no difference in devaluation is observed between these training conditions. This result suggests that the strength of the devaluation effect is not influenced by the number of commission errors.

Together, Experiments 1 and 2 showed that an explicit no-go cue does not cause larger devaluation, which is not in line with the no-go cue EC account. However, in both experiments the no-go cue was still provided. In the next experiment, we used a more simplified version of the training by leaving out the no-go cue altogether, to explore whether the devaluation effect could still be observed.

Experiment 3

In Experiment 3, we included only go and no-cue trials, to further test whether the no-go cue was required for the devaluation effect. If in this case no-cue foods were not devalued, it would suggest that the no-go cue is still needed in the training, though not on every nonresponse trial. However, if the no-cue foods were still devalued, it would strongly suggest that the devaluation of no-go foods is not caused by no-go cue.

Method

Participants. Forty-five participants participated in the experiment. Two participants were excluded since their accuracies on either go or no-cue trials were 3 *SD* below the mean (preregistered). Forty-three participants remained in the final sample (9 males, 34 females, $M_{age} = 23.8$ years, $SD_{age} = 7.6$).

Materials and procedure. The same materials and general procedures were used as in Experiment 1. The only difference was that in GNG, we presented 20 pictures on go trials (without the staircase procedure), and 20 pictures on no-cue trials. The no-go cue was not provided. The remaining 10 pictures were again used as untrained baseline.

Results

The main effect of training condition on difference score in repeated-measures ANOVA was significant, $F(2, 84) = 8.52$, $p < .001$, $\eta^2 = .169$ (see Figure 2). The difference scores were: untrained, $M = -8.59$, $SD = 12.88$; go, $M = -7.28$, $SD = 10.63$; no-cue, $M = -14.65$, $SD = 13.26$. Paired-samples *t* tests showed that the difference score of no-cue foods was significantly lower than that of untrained foods, $M = -6.06$, $SE = 2.07$, $t(42) = -2.92$, $p = .006$, $d_{unb} = -0.455$, 95% CI [−0.787, −0.135], and go foods, $M = -7.37$, $SE = 1.70$, $t(42) = -4.34$, $p < .001$, $d_{unb} = -0.601$, 95% CI [−0.915, −0.304]. In line with Experiments 1 and 2, we showed the devaluation effect for no-cue foods, when the no-go cue was not provided at all in the whole training. The difference between go and untrained foods was not significant, $M = 1.31$, $SE = 1.92$, $t(42) = 0.68$, $p = .500$, $d_{unb} = 0.109$, 95% CI [−0.210, 0.430], BF = 0.205.

Discussion

In this experiment, we did not provide no-go cue altogether. The devaluation effect was again observed, suggesting that the devaluation effects we observed in Experiments 1 and 2 were not due to the occasional presence of no-go cue.

Across Experiments 1 to 3, we consistently showed the devaluation effect when participants did not respond to palatable food stimuli, regardless of the presence of no-go cues. These results strongly indicate that the devaluation effect is independent of no-go cues, which contradicts the prediction of the no-go cue EC account. Second, by adopting both go and untrained stimuli as baselines, our results provide a very strong demonstration of the devaluation effect. After ruling out the no-go cue EC account, we tested the nonresponse EC account against the response inhibition account in the next part.

Experiment 4a

Not responding may cause devaluation either via the evaluative meaning of not responding or via response inhibition. To test the nonresponse EC account and the response inhibition account, we varied the percentage of no-go trials from 25% to 75%. The nonresponse EC account predicts devaluation with both low and high proportion of no-go trials. The response inhibition account, on the other hand, predicts devaluation only when the proportion of no-go trials is relatively low, or at least not higher than go trials (e.g., Experiments 1–3; Veling et al., 2008). In Experiment 4a, we first lowered the percentage of no-go trials to 25% to see how this would influence the devaluation effect. In Experiment 4b, the percentage of no-go trials was increased to 75%. Because previous neuroscience studies have shown the involvement of the inhibition system (i.e., rIFC) during go/no-go task (Berkman et al., 2009; Konishi et al., 1998, 1999) especially when go trials are more frequent (e.g., Bruin & Wijers, 2002; Nakata et al., 2005), and because one specific form of EC, namely the no-go cue EC account, was ruled out in Experiments 1 to 3, we expected to obtain evidence for the response inhibition account. Therefore, we predicted devaluation for 25% no-go (Experiment 4a) but weaker or no devaluation for 75% no-go (Experiment 4b) in our preregistrations of Experiments 4a and 4b.

At the end of the experiments, we added a recall task in which participants were asked to indicate, for each food picture, whether it was a go or no-go stimulus. This recall task was included as a measurement for the amount of attention participants paid to the training task, under the assumption that participants who paid more attention to the training would show a better memory for the associations. This was important because we wanted to rule out that any null effects of the training on evaluations in the experiments (e.g., the predicted null effect in Experiment 4b) could be explained by a lack of attention to the task. For instance, participants might pay less attention to the training in Experiment 4b because this version only required occasional responding. The absence of devaluation in Experiment 4b could then be explained by the fact that participants were not paying a sufficient amount of attention, rather than by the absence of response inhibition. Indeed, recent research showed that attention might play an important role in learning the associations between stimuli and stopping responses (Best, Lawrence, Logan, McLaren, & Verbruggen, 2016). In sum, the recall task was included to address differences in attention as an alternative explanation for differences in devaluation effects across studies.

Method

Sample size. Because no difference was observed between no-go and no-cue stimuli from Experiments 1 to 3, we combined them into nonresponse stimuli. These nonresponse stimuli were then compared with go and untrained stimuli for conducting a power analysis. When untrained stimuli were used as baseline, the average effect size of devaluation was Cohen's $d_{unb} = -0.537$, 95% CI [−0.724, −0.350]; when go stimuli were used as baseline, the average effect size was Cohen's $d_{unb} = -0.697$, 95% CI [−0.999, −0.394] (meta-analyzed with ESCI, see Cumming, 2012). We used Cohen's $d_{unb} = -0.537$ as the expected effect size in our own setup and calculated the required sample size to be 30 for achieving 80% power. The planned sample sizes for Experiments 4 to 6 were therefore determined to be at least 30 to achieve sufficient power.

Participants. Thirty participants took part in the experiment. Two were excluded due to low accuracies in GNG (3 *SD* below the mean). One correctly indicated the study aim and was excluded. Exclusion criteria were not preregistered; however, exclusion of participants did not change the results. Twenty-seven participants remained (3 males, 24 females, $M_{age} = 23.3$ years, $SD_{age} = 4.67$). Because of exclusion, the achieved power was 76.6% (Faul et al., 2009).

Materials and procedure. The same general procedure from Experiment 1 was used. In Experiments 4 to 6, participants were asked to fast for at least 3 hours instead of 4. In addition, these experiments were conducted independently. In GNG, we presented 30 pictures on go trials and 10 pictures on no-go trials so that 25% of the trials were no-go trials. Although the no-go cues are not needed in the training (see Experiments 1–3), we kept both go and no-go cues in the task so that the go and no-go trials were similar with regard to the number of events per trial. For this experiment, and all subsequent experiments, the pictures were repeated 6 times in GNG. After the second evaluation, participants received a recall task in which all the 40 pictures from GNG were presented one by one, and they indicated for each picture whether it was associated with responding or not responding in the training.

Results

The main effect of training condition was significant, $F(2, 52) = 9.85$, $p < .001$, $\eta^2 = .275$ (see Figure 3). The difference scores were: untrained, $M = -10.97$, $SD = 13.28$; go, $M = -6.58$, $SD = 9.79$; no-go, $M = -19.04$, $SD = 19.85$. The difference score of no-go foods was significantly lower than untrained foods, $M = -8.06$, $SE = 2.86$, $t(26) = -2.82$, $p = .009$, $d_{unb} = -0.464$, 95% CI [−0.830, −0.118], and go foods, $M = -12.45$, $SE = 3.34$, $t(26) = -3.73$, $p = .001$, $d_{unb} = -0.773$, 95% CI [−1.261, −0.319], replicating the devaluation effect. The difference score of go foods was marginally significantly higher than untrained foods, $M = 4.39$, $SE = 2.23$, $t(26) = 1.97$, $p = .060$, $d_{unb} = 0.366$, 95% CI [−0.015, 0.762]. The percentage of correct responses in the recall task was calculated for each participant. On average, participants showed good memory of the associations, $M = 80.2\%$, $SD = 16.0\%$, indicating that they paid attention to the training.

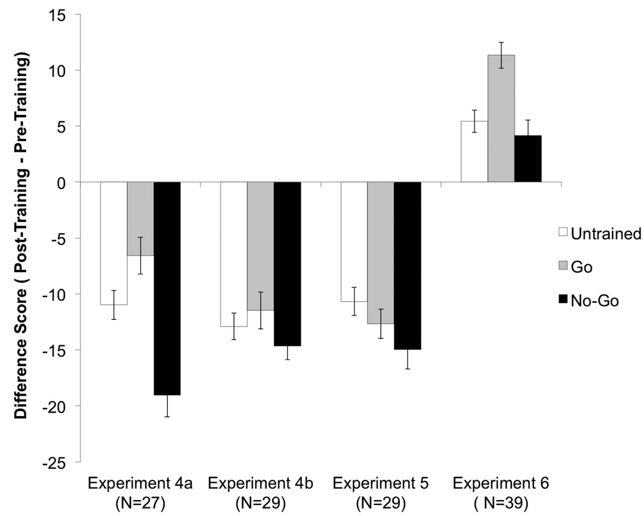

Figure 3. Difference scores (posttraining–pretraining evaluation) for different food training conditions in Experiments 4 and 6. Error bars stand for within-subject standard errors.

Experiment 4b

Method

Participants. Thirty-one participants were recruited. Three participants' accuracy scores on no-go trials were 3 *SD* below the mean. However, this was attributable to the overall high accuracy scores of all the participants (see Table 2), rather than low performance of these three participants (their scores were around 95%). These three participants were therefore kept in the analysis. One participant correctly indicated the study aim and was excluded. One participant indicated not understanding part of the instruction (in Dutch) and was excluded. Exclusion criteria were not preregistered; however, exclusion of participants did not change the results. Twenty-nine participants remained in the final sample (5 males, 24 females, $M_{age} = 21.2$ years, $SD_{age} = 2.31$). The achieved power was 79.7%.

Materials and procedure. For GNG in the current experiment, we presented 10 pictures consistently on go trials and 30 pictures on no-go trials. The percentage of no-go trials thus increased to 75%. The rest remained the same as in Experiment 4a.

Results

The main effect of training condition was not significant, $F(2, 56) = 0.89$, $p = .418$, $\eta^2 = .031$, BF = 0.204 (see Figure 3). The difference scores were: untrained, $M = -12.89$, $SD = 9.92$; go, $M = -11.47$, $SD = 14.76$; no-go, $M = -14.63$, $SD = 9.55$. The difference score of no-go foods did not differ significantly from that of untrained foods, $M = -1.73$, $SE = 1.78$, $t(28) = -0.98$, $p = .338$, $d_{unb} = -0.173$, 95% CI [−0.537, 0.184], BF = 0.305, and that of go foods, $M = -3.16$, $SE = 2.66$, $t(28) = -1.19$, $p = .244$, $d_{unb} = -0.247$, 95% CI [−0.677, 0.172], BF = 0.374.[6] The difference score of go foods did not differ significantly from that of untrained foods, $M = 1.43$, $SE = 2.60$, $t(28) = 0.55$, $p = .587$, $d_{unb} = 0.110$, 95% CI [−0.293, 0.518], BF = 0.227. The average accuracy in the recall task was $M = 80.7\%$, $SD = 20.0\%$.

To directly compare devaluation effects of Experiments 4a and 4b, we first calculated two devaluation scores for each participant by subtracting the difference scores of untrained and go foods from the no-go foods (i.e., devaluation_1 = difference score of no-go—difference score of untrained; devaluation_2 = difference score of no-go—difference score of go). A lower devaluation score stands for a stronger effect. These devaluation scores were then compared between experiments with independent samples *t* tests. When untrained foods were used as baseline, the devaluation score was significantly lower in Experiment 4a than in Experiment 4b, $M = -6.33$, $SE = 3.32$, $t(54) = -1.91$, $p = .031$ (one-tailed), $d_{unb} = -0.503$, 95% CI [−1.041, 0.025]; when go foods were used as baseline, the devaluation score was again significantly lower in Experiment 4a, $M = -9.29$, $SE = 4.24$, $t(54) = -2.19$, $p = .016$ (one-tailed), $d_{unb} = -0.578$, 95% CI [−1.119, −0.048]. Both analyses suggested stronger devaluation effects when no-go trials were rare.

Moreover, the accuracies from the recall task did not differ between Experiments 4a and 4b, $t(54) = 0.104$, $p = .918$, BF = 0.271, suggesting that the absence of devaluation in Experiment 4b was not due to lower attention to the training. Both devaluation effects remain stronger in Experiment 4a than in Experiment 4b when memory is entered as a covariate in ANCOVA. In sum, the devaluation effects were present in Experiment 4a, but not in 4b, which is in line with the prediction of the response inhibition account.

Discussion

In Experiments 4a and 4b, we employed a percentage of no-go trials of 25% and 75% respectively. In line with the prediction of the response inhibition account, devaluation was observed in Experiment 4a where the percentage of no-go trials was relatively low, but not in Experiment 4b where the no-go trials were more frequent. Increasing frequency of no-go trials did not lead to devaluation. The nonresponse EC account therefore does not fit with the empirical evidence.

In both Experiments 4a and 4b, participants showed high levels of memory for the associations between food stimuli and cues, whereas the devaluation effect was observed only in Experiment 4a. The absence of devaluation in Experiment 4b is therefore unlikely the result of less attention to the GNG. Moreover, this finding suggests that high level of memory for stimulus-cue associations is not sufficient to induce devaluation effects. In the next experiment we further tested whether merely not responding to stimuli could lead to devaluation by asking participants to simply observe the training. If merely not responding to stimuli leads to devaluation, both go and no-go stimuli should be devalued compared to untrained stimuli, while the response inhibition account again predicts no devaluation (i.e., no difference between no-go and untrained stimuli), as the inhibition process is not engaged.

Experiment 5

In Experiment 5, we used the same procedure as in Experiment 4a, but changed the task. Instead of actually performing the GNG, participants were instructed to view the training and try to remember the associations between foods and cues. The memory instruction was given to participants to ensure that they would pay attention to the training, and to make sure memory of the associations would be at least as high as in Experiment 4a. The absence of devaluation in this case would again suggest that merely not responding without response inhibition is not sufficient for devaluation.

Method

Participants. Thirty-nine participants took part in the experiment. Five participants were excluded because they made responses in GNG (counter to the instructions), and another 5 were excluded since their memory accuracy was lower than 50%, suggesting that they may have remembered the association wrongly (preregistered exclusion criteria). Twenty-nine participants remained in the final analysis (5 males, 24 females, $M_{age} = 22.0$ years, $SD_{age} = 3.05$). The achieved power was 79.7%.

Materials and procedure. The same procedure was used as in Experiment 4a. Participants first read the instruction for GNG, and received the practice block to ensure the go and no-go cues were represented as cues for responding and withholding responses, respectively. However right before the experimental blocks, they were instructed to not do the training, but instead just watch the training and try to remember for each picture whether it was paired with responding or not responding. At the end of the experiment they were asked to indicate how often they looked at the pictures during GNG (1 = *never*; 2 = *sometimes*; 3 = *about half of the time*; 4 = *most of the time*; 5 = *all the time*).

Results

Of the 29 participants in the final sample, 16 reported looking at the pictures all the time; 12 looked most of the time; 1 looked about half of the time. In general, participants paid attention to GNG according to their self-report. In line with the self-report, they also showed high memory, $M = 90.5\%$, $SD = 10.9\%$, confirming that they indeed paid attention to the task and learned the associations.

The main effect of training condition was not significant, $F(2, 56) = 1.44$, $p = .246$, $\eta^2 = .049$, BF = 0.316 (see Figure 3). The difference scores were: untrained, $M = -10.66$, $SD = 9.72$; go,

[6] For one participant the difference between no-go and go stimuli was 3 *SD* from the mean. Deleting this participant led to normal distribution, and the result was the same, $M_{nogo\text{-}go} = -1.53$, $SE = 2.18$, $t(27) = -0.70$, $p = .488$, $d_{unb} = -0.127$, 95% CI [−0.495, 0.236], BF = 0.251.

$M = -12.66$, $SD = 10.40$; no-go, $M = -14.95$, $SD = 16.44$. The difference score of no-go foods did not differ significantly from that of untrained foods, $M = -4.29$, $SE = 2.77$, $t(28) = -1.55$, $p = .133$, $d_{unb} = -0.309$, 95% CI [−0.725, 0.096], BF = 0.573, and also did not differ significantly from that of go foods, $M = -2.29$, $SE = 2.83$, $t(28) = -0.81$, $p = .424$, $d_{unb} = -0.162$, 95% CI [−0.570, 0.240], BF = 0.267.[7] The difference between go and untrained stimuli was also not significant, $M = -1.99$, $SE = 1.89$, $t(28) = -1.06$, $p = .300$, $d_{unb} = -0.193$, 95% CI [−0.568, 0.175], BF = 0.327.

Discussion

In Experiment 5, we used the procedure from Experiment 4a but changed the task, so that participants learned the associations between food stimuli and cues without actually receiving the training. In this way participants did not respond, but the response inhibition process was eliminated. Devaluation was again absent, indicating that in line with the response inhibition account, merely not responding without engaging in response inhibition did not cause devaluation. Furthermore, participants reported that they paid attention to the training task, and they also displayed a high level of memory for the associations between stimuli and cues. Hence, the absence of a devaluation effect in Experiment 5 cannot easily be explained by a lack of attention to the task.

Experiment 6

In Experiments 1 to 5, we used highly appetitive stimuli to investigate the devaluation effect. Hence, it is unclear whether relatively low valued stimuli can also be devalued through the same training procedure. Some previous work with GNG found the devaluation effect only for positive stimuli, or in a sample for which the target stimuli were rewarding, but not for neutral stimuli (e.g., Houben, 2011; Veling et al., 2008, 2011, 2013b). On the other hand, devaluation of neutral and negative no-go stimuli compared with go stimuli has also been demonstrated (Frischen, Ferrey, Burt, Pistchik, & Fenske, 2012; but see Koster, Duzel, & Dolan, 2015, in which negative no-go stimuli were evaluated more positively than negative go stimuli in a choice-induced preference change paradigm). This inconsistency in the literature may be attributable to the employment of different baselines. Specifically, studies showing devaluation of neutral and negative stimuli employed only one baseline (i.e., go stimuli), so it is unclear whether this effect is due to increased evaluations of go stimuli or decreased evaluations of no-go stimuli. Experiment 6 was carried out to explore the devaluation effect on relatively low rated stimuli by using the same general procedure of the current research, where two baselines were employed.

Method

Participants. Forty-two participants were recruited. Two participants whose accuracies on go or no-go trials were 3 *SD* below the mean were excluded (preregistered exclusion criterion). Another participant correctly indicated the study aim and was also excluded (exclusion did not change the results). Thirty-nine participants remained in the final sample (6 males, 33 females, $M_{age} = 22.7$ years, $SD_{age} = 4.02$).

Materials and procedure. The same procedure from Experiment 4a was used. The only difference was that we selected the 50 pictures with the lowest ratings (average rating before training = −7.06, $SE = 3.34$, on a scale from −100 to 100) and used them in GNG and the second evaluation.

Results

The main effect of training condition was significant, $F(2, 76) = 6.91$, $p = .002$, $\eta^2 = .154$ (see Figure 3). The difference scores were: untrained, $M = 5.43$, $SD = 11.62$; go, $M = 11.33$, $SD = 10.52$; no-go, $M = 4.15$, $SD = 11.49$. Different from previous experiments, the difference scores were all positive, which is again likely attributable to regression to the mean. The difference score of no-go foods did not differ significantly from untrained foods, $M = -1.28$, $SE = 2.12$, $t(38) = -0.60$, $p = .550$, $d_{unb} = -0.109$, 95% CI [−0.471, 0.251], BF = 0.205, while it was significantly lower than that of go foods, $M = -7.18$, $SE = 2.35$, $t(38) = -3.06$, $p = .004$, $d_{unb} = -0.639$, 95% CI [−1.091, −0.205].[8] The difference score of go foods was significantly higher than that of untrained foods, $M = 5.90$, $SE = 1.65$, $t(38) = 3.57$, $p = .001$, $d_{unb} = 0.522$, 95% CI [0.214, 0.845]. The memory accuracy was $M = 73.1\%$, $SD = 14.7\%$.

Discussion

In Experiment 6, we selected relatively low valued food pictures and used them in the training. In line with previous findings (Frischen et al., 2012), go stimuli were rated more positively than no-go stimuli. However, comparing go and no-go stimuli to the untrained baseline suggests that this difference could be more parsimoniously explained as a potential valuation effect of go stimuli, rather than devaluation of no-go stimuli. This might explain the seemingly inconsistent findings in the literature, as different baselines were often employed in different studies.

The absence of devaluation effect for relatively low-rated stimuli is in line with the BSI theory, which explicitly predicts that response inhibition leads to devaluation, but only for appetitive stimuli. A pure response inhibition account may predict devaluation for positive, neutral and negative stimuli alike (Frischen et al., 2012). Nonetheless, the absence of devaluation for relatively low rated stimuli could still be post hoc explained by the response inhibition account. For instance, less appetitive stimuli may attract less attention compared to appetitive stimuli, and task attention might determine the learning of the associations between stimuli and response inhibition. Indeed, the memory recall accuracy in Experiment 6 was lower than in Experiment 4a, (73.1% vs. 80.2%), which could be attributable to less attention paid to lowly rated stimuli, but this comparison did not reach significance,

[7] For 1 participant the difference between no-go and go stimuli was 3 *SD* away from the mean. Deleting this participant improved the normal distribution and led to the same results, $M_{nogo\text{-}go} = -0.61$, $SE = 2.35$, $t(27) = -0.26$, $p = .797$, $d_{unb} = -0.054$, 95% CI [−0.474, 0.364], BF = 0.207.

[8] Excluding 5 participants whose difference between go and no-go stimuli was 1.5 *SD* away from the mean led to normal distribution. The difference between no-go and go foods became marginally significant, $M = -2.57$, $SE = 1.44$, $t(33) = -1.78$, $p = .084$, $d_{unb} = -0.284$, 95% CI [−0.616, 0.038].

$t(64) = -1.867$, $p = .067$. Nevertheless, all else being equal, response inhibition to neutral stimuli does not lead to devaluation, whereas response inhibition to appetitive stimuli does.

General Discussion

To gain more insight into the underlying mechanism of GNG in influencing evaluations, the current research examined two potentially important task components, namely the no-go cue and not responding. To explore the role of the no-go cue in causing devaluation, in the first part we manipulated the presence of no-go cues independently of not responding. Results showed appetitive stimuli were evaluated as less attractive when participants did not respond to them, regardless of the presence of no-go cues. Devaluation was also observed when the timing of the 'implicit' no-go cue was made less clear and when the no-go cue was not provided altogether. The no-go stimuli were devalued compared with both untrained and go stimuli. Devaluation of no-go stimuli can hence not be explained by increased evaluations of go stimuli or exposure in the GNG. Overall, the devaluation effect appears not to be contingent on the no-go cue, suggesting that the effect is driven by not responding, but not by no-go cue. This conclusion is further corroborated by the results of Experiment 5. In Experiment 5, participants were instructed to memorize the associations between stimuli and go and no-go cues. Despite high levels of memory, learning these associations did not cause lower evaluations of no-go stimuli. Together, these experiments do not support the no-go cue EC account of the devaluation effect.

In the second part, we examined the nature of not responding in causing the devaluation effect. The nonresponse EC account and the response inhibition account were pitted against each other. Across Experiments 4a and 4b we varied the percentage of no-go trials to 25% and 75%. In line with the response inhibition account and our predictions, devaluation occurred when the percentage of no-go trials was 25%, but disappeared when the percentage of no-go trials increased to 75%. In Experiment 5, we used the same procedure from Experiment 4a (i.e., 25% no-go trials) but instructed participants to learn associations without performing the training. The devaluation effect was again absent. In Experiment 6 we explored whether the 25% no-go training would devalue lowly rated stimuli, and found no devaluation. Based on these findings, we conclude devaluation is not caused by the evaluative meaning of not responding. Merely not responding is not sufficient to cause devaluation; instead, devaluation occurs when people inhibit their responses toward appetitive stimuli in a context of frequent responding.

Taken together, these results rule out two EC accounts and support the response inhibition account. Response inhibition training by means of GNG is therefore not just a specific form of evaluative conditioning. Our results are in line with the previous correlational neuroscience findings (Kiss et al., 2008; see also Berkman et al., 2009); furthermore, by manipulating the percentage of no-go trials, we provide strong behavioral evidence for the causal role of response inhibition in devaluation.

Comparison Between SST and GNG

As mentioned in the introduction, both SST and GNG are used as response inhibition trainings. Although they are often used interchangeably, recently there are some debates on the differences between these two tasks (Verbruggen & Logan, 2008; Wessel et al., 2014). In GNG, both the go and no-go cues are provided. Participants respond when they perceive a go cue, and do not respond when they perceive a no-go cue. The percentages of go and no-go trials are often equal. In SST, only the no-go cue (i.e., the stop signal) is provided. Participants respond when there is no cue, and do not respond when they perceive a no-go cue. The percentage of no-go trials is often lower than go trials and a staircase procedure is often implemented on no-go trials (i.e., presentation of the no-go cue is delayed in the next no-go trial after a successful stop) to discourage waiting for the no-go cue. Some researchers have accordingly argued that SST is more clearly about stopping an ongoing response, whereas GNG is more like a decision-making paradigm, in which participants simply decide to respond or not (Wessel et al., 2014). This view does not entirely fit with the current findings, because if simply deciding to respond or not is sufficient to cause devaluation, we would observe a devaluation effect in both 25% no-go and 75% no-go version of the training, and may even find the effect when participants observed the training. The underlying mechanism of GNG appears therefore also to be response inhibition.

SST and GNG differ in the percentage of no-go trials. Based on the current findings, one might expect SST to be more effective than GNG, as in SST 25% of the trials are no-go trials, which should more strongly engage the inhibition system. However, the result of a recent meta-analysis showed the opposite: studies employing GNG yielded an effect size of Cohen's $d^+ = 0.503$, 95% CI [0.348, 0.658], whereas SST yielded a smaller effect size, $d^+ = 0.190$, 95% CI [0.000, 0.380] (Allom et al., 2015). A key difference between the 25% no-go version of GNG in the current study and the SST is that due to the implementation of a staircase procedure on no-go trials in the SST, the proportion of successful inhibition on no-go trials is typically lower in the SST than in GNG. The proportion of successful inhibition has been shown to be a significant predictor of the training effects (Jones et al., 2016), so that a higher proportion of inhibition leads to a larger devaluation effect. This suggests that for the training to be effective, people must form associations between appetitive stimuli and the successful inhibition of response. A second observation is that the devaluation effect in 25% no-go (Experiment 4a) is $d_{unb} = -0.464$, 95% CI [−0.830, −0.118], while the average devaluation effect in 50% no-go (in Experiments 1–3, where half of the trials were nonresponse trials) is $d_{unb} = -0.537$, 95% CI [−0.724, −0.350] (using untrained stimuli as baseline). Descriptively, these two effect sizes are very similar, and the magnitudes also converge with the results of recent meta-analyses (Allom et al., 2015; Jones et al., 2016; Turton et al., 2016). This suggests that including 50% no-go trials may already be sufficient to engage the inhibition system, and decreasing the amount of no-go trials may not further enhance the effectiveness.

How Does Inhibition Cause Devaluation?

Although the current research suggests that devaluation of appetitive stimuli is caused by response inhibition, how response inhibition causes devaluation exactly still remains an important question that awaits future research. Previous work on distracter devaluation has shown that stimuli ignored in visual search are evaluated more negatively than attended or novel stimuli (for a review, see Fenske & Raymond, 2006), an effect similar to devaluation induced by response inhibition. To explain this distractor-devaluation effect, an attentional inhibition account has been proposed, which posits that during visual search, associations between attentional inhibition and ignored stimuli are established and when ignored stimuli are encountered in later evaluations, these associations are reinstantiated (Goolsby, Shapiro, & Raymond, 2009). A similar response inhibition account can be proposed for the current findings. These accounts, however, do not directly answer how inhibition leads to devaluation. Three different accounts may be proposed to explain this association between inhibition and devaluation.

First, according to the BSI theory, the automatic approach tendency triggered by appetitive stimuli and the task requirement of inhibition constitute a conflict, and conflict signal is generally experienced as aversive (Dreisbach & Fischer, 2015). A second explanation is that inhibiting one's attention or one's motor responses may both activate inhibition process, which may have spillover effects on other brain areas that encode affective responses (Berkman et al., 2009). A third explanation is that the inhibition process may occupy visual working memory capacity (Chiu & Egner, 2015a, 2015b; Goolsby et al., 2009), leaving fewer attentional resources for representing the stimuli encountered during inhibition. Less accurate representation of the no-go stimuli may then lead to lower evaluations. More studies are still needed to delineate the neurological and cognitive mechanism of how inhibition causes devaluation.

Potential Valuation Effects for Go Stimuli

For exploratory reasons, we also compared evaluations of go stimuli with untrained stimuli in each experiment. Consistent with previous findings (Veling et al., 2008), when half of the trials were go trials, as in Experiments 1 and 3, responding to appetitive stimuli did not further increase their evaluations. However, when the staircase procedure was implemented on go trials, which required rapid go responses, a valuation effect for go stimuli was observed (in Experiment 2). Interestingly, this result appears consistent with recent findings from cue-approach training (Schonberg et al., 2014). Responding rapidly to go stimuli may lead participants to allocate more attention to these stimuli, and increased attention to go stimuli may increase the value of these stimuli (Schonberg et al., 2014).

Furthermore, Experiments 4a and 6 (which employed 25% no-go trials) suggest that responding to go stimuli frequently on a task-level may also increase the evaluation of go stimuli. This finding may post hoc be understood in light of work on the interaction between action and valence. This work has shown that similar brain areas underlie the anticipation of go actions and the responses to reward (Guitart-Masip et al., 2014). Extra engagement of the go circuitry may be required to generate rapid go responses (as in Experiment 2) or when the go responses are anticipated to be frequent (Experiments 4a and 6). This engagement may lead to the valuation of go stimuli. Future research can more systematically investigate this potential valuation effect by manipulating task characteristics and adopting multiple baselines.

Implications for Behavioral Interventions

Because the response inhibition trainings discussed in the current paper are being developed into behavioral interventions for problematic behaviors, some suggestions can be given based on our results. First, since the devaluation effect is not driven by the no-go cue, the no-go cue can be omitted, which may provide more flexibility in designing interventions. Second, the percentage of no-go trials should not be higher than go trials, otherwise the inhibition process may not be engaged and the training may be rendered ineffective. Third, making participants responding rapidly or frequently to go stimuli may increase the evaluation of these stimuli, which might be useful if an alternative behavior can be enhanced to replace the unwanted behavior.

One remaining question that is of both theoretical and practical importance is to what extent the devaluation effect caused by response inhibition generalizes to new stimuli. All experiments in the current research used untrained stimuli as a baseline, which assumed no generalization. To support this assumption, the untrained stimuli were not devalued compared to go stimuli (in Experiments 1 and 3, see also Veling et al., 2008), suggesting that the devaluation effect is specific to the trained food and does not generalize. It is important to examine whether the devaluation effect is indeed stimulus-specific, or whether this lack of generalization in the current context was caused by the stimuli used (e.g., different food pictures that do not share visual features) or specific task characteristics (e.g., presenting food pictures on both go and no-go trials). Future studies can further investigate whether the devaluation effect generalizes to untrained foods that share certain features with no-go foods, and whether certain procedural change (e.g., presenting nonfood stimuli on go trials and food stimuli on no-go trials, as already implemented in some training procedures) may facilitate the generalization of devaluation.

Limitations and Future Directions

The results of the current research fit with the response inhibition account. However, the inhibition process was not directly measured. It remains interesting to test how the involvement of inhibition may be moderated by task characteristics and how this relates to devaluation. A related question is whether inhibiting motor responses specifically, or a general inhibition process, is responsible for devaluation. Neuroimaging tools such as EEG and fMRI are needed to answer these questions in future research.

In all experiments, explicit stimulus evaluations were used as the dependent variable. This makes it possible to directly compare results across experiments, and connects the present work to research on evaluative conditioning (Hofmann et al., 2010). Evaluations can also be measured indirectly by implicit measures (e.g., implicit association test and affective priming task, De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009). Using this kind of measure to assess evaluation of no-go stimuli, however, may impose a methodological challenge. Research suggests that responses toward no-go stimuli slow down after participants acquire the stimulus-stop associations (Best et al., 2016; Bowditch et al., 2016; Giesen & Rothermund, 2014), and because implicit evaluations are often inferred from RTs, the implicit measurement of evaluation could be influenced by such associations. Future studies may overcome this challenge by using indirect measures that are not based on RTs (e.g., the affective misattribution procedure, Payne, Cheng, Govorun, & Stewart, 2005).

In addition to evaluations, the effect of training can also be assessed with other behavioral measurements, for instance by asking participants to indicate their choice for food items, or their willingness to pay (WTP; Schonberg et al., 2014; Wessel et al., 2014). We are now conducting new studies along these lines, and preliminary results suggest that GNG as employed here also influences snack choices (see also Veling et al., 2013a, 2013b) and WTP for snacks. However, we aim to conduct a series of studies (including exact replications and preregistered studies) using these dependent measures before drawing conclusions with regard to the effectiveness of the currently employed go/no-go training on influencing food choice and WTP for food items.

In Experiments 4 through 6, we included a memory recall task to assess participants' memory of the stimulus-cue associations. Participants showed high levels of memory across all experiments, while the devaluation effect was only observed when they had to inhibit their response toward highly appetitive stimuli. This finding suggests that remembering these associations is not a sufficient condition for the devaluation effect. Although it does not seem sufficient, memory for the associations may still be a necessary component for devaluation of no-go stimuli. Future research may experimentally manipulate memory to further observe its role in devaluation.

Finally, we recruited predominantly female college students as participants. Because of this recruitment strategy, the samples were homogeneous in terms of demographics, BMI and restraint eating scores (see supplementary material). Recruiting homogenous samples precludes potential alternative explanations in interpreting the results across experiments, but also raises the question whether the devaluation effect can also be found with different samples, for instance male participants and people with a relatively high BMI. Replications in such samples are needed to assess the generalizability of the present findings.

Conclusion

In the current project, we investigated how not responding to appetitive stimuli (e.g., attractive food) causes devaluation. We showed that this devaluation effect is not due to the association between stimuli and the no-go cue; furthermore, it is not caused by the association between stimuli and the evaluative meaning of not responding. The underlying mechanism of devaluation is qualitatively different from evaluative conditioning; it is driven by inhibiting prepotent go response toward appetitive stimuli in a context of frequent responding. Across 6 experiments, we consistently and reliably showed the devaluation of no-go stimuli in comparison with both go stimuli and untrained stimuli when response inhibition was engaged. Potential valuation effect of go stimuli was occasionally observed when participants engaged in rapid or frequent responding; however, these findings were not a priori predicted and should be more systematically investigated. Overall, these results shed more light on the underlying mechanism of response inhibition training and also have implications for applied behavioral change interventions.

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Correction to Payne et al. (2016)

In the article "Replicable Effects of Primes on Human Behavior" by B. Keith Payne, Jazmin L. Brown-Iannuzzi, and Chris Loersch (*Journal of Experimental Psychology*: *General*, Vol. 145. No. 10, pp. 1269–1279. http://dx.doi.org/10.1037/xge0000201), the graph in Figure 5 did not contain the asterisk mentioned in the figure caption, which was intended to indicate a statistically significant difference between bet and pass prime. The online version of this article has been corrected.

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