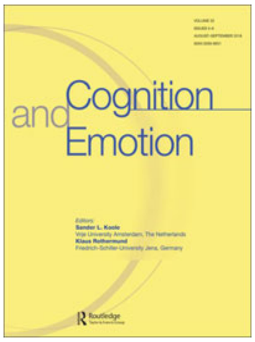

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Devaluation of NoGo stimuli is both robust and fragile

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ABSTRACT

Consistently not responding to stimuli during go/no-go training leads to lower evaluations of these NoGo stimuli. How this NoGo-devaluation-effect can be explained has remained unclear. Here, we ran three experiments to test the hypothesis that people form stimulus-stop-associations during the training, which predict the strength of the devaluation-effect. In Experiment 1, we tried to simultaneously measure the stimulus-stop-associations and NoGo-devaluation, but we failed to find these effects. In Experiment 2, we measured NoGo-devaluation with established procedures from previous work, and stimulus-stop-associations with a novel separate task. Results revealed a clear NoGo-devaluation-effect, which remained visible across multiple rating blocks. Interestingly, this devaluation-effect disappeared when stimulus-stop-associations were measured before stimulus evaluations, and there was no evidence supporting the formation of the stimulus-stop-associations. In Experiment 3, we found evidence for the acquisition of stimulus-stop-associations using an established task from previous work, but this time we found no subsequent NoGo-devaluation-effect. The present research suggests that the NoGo-devaluation-effect and stimulus-stop-associations can be found with standard established procedures, but that these effects are very sensitive to alterations of the experimental protocol. Furthermore, we failed to find evidence for both effects within the same experimental protocol, which has important theoretical and applied implications.

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People often respond to environmental stimuli in ways leading to adaptive outcomes. For example, they start walking when a traffic light turns green, and stop walking when it turns red. These stimulus-response associations[1] enable us to survive in an environment full of complex and unpredictable events (Murphy & Honey, 2015). However, some stimulus-response associations may cause detrimental outcomes in the long run. For instance, food items or alcoholic beverages may elicit approach responses acquired through basic learning mechanisms such as Pavlovian or Instrumental conditioning, which may ultimately lead to overconsumption of such products (Di Lemma & Field, 2017; Houben et al., 2012; Watson et al., 2014). Thus, studying how to modify people's Go and NoGo responses to stimuli has attracted considerable interest (e.g. Jones et al., 2016). Here we aim to gain more insight into the nature of the associations people acquire with stimuli when they repeatedly respond or not respond to specific stimuli during go/no-go training.

Previous research employed the go/no-go training (GNG) to modify people's responses to specific stimuli (Jones et al., 2016; Turton et al., 2016; Veling, Chen, et al., 2017; Veling, Lawrence, et al., 2017). During this training, Go or NoGo cues are consistently presented in close temporal proximity to target stimuli. Participants consistently respond to some stimuli

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when Go cues are presented (Go stimuli), and withhold their responses when NoGo cues are presented (NoGo stimuli). An interesting finding is that such training can influence both food and alcohol consumption when pictures of these products were presented as NoGo stimuli during GNG (Adams et al., 2017; Chen et al., 2019; Houben & Jansen, 2011). Yet, what causes such behaviour change has remained unclear. A recent theoretical analysis of the various possible mechanisms (Veling, Chen, et al., 2017; Veling, Lawrence, et al., 2017) suggests two candidate mechanisms: GNG modifies people's behaviour via affective responses toward specific stimuli (Chen et al., 2016) or altering motor responses (Verbruggen & Logan, 2008). Note that these two mechanisms are not mutually exclusive, but may both point to changes in a motivational system that influences both motor and affective responses toward stimuli (Custers & Aarts, 2010; Verbruggen et al., 2014).

The NoGo-devaluation-effect

First, GNG can influence stimulus evaluations, such that NoGo stimuli are rated as relatively less attractive than Go stimuli, and stimuli that are not presented during the training (untrained stimuli; Veling et al., 2008), which is called the *NoGo-devaluation-effect* (e.g. Chen et al., 2016). Reduced evaluations of NoGo stimuli compared to Go and/or untrained stimuli have been shown for human faces (Kiss et al., 2008), abstract art-like patterns (Clancy et al., 2019; Frischen et al., 2012), erotic stimuli (Ferrey et al., 2012), high-calorie foods (Houben & Giesen, 2018), smoking-related stimuli (Scholten et al., 2019), alcohol-related stimuli (Houben et al., 2011, 2012) and smartphone-app icons (Johannes et al., 2021). There is also some evidence that the NoGo-devaluation-effect mediates effects of GNG on behaviour (Johannes et al., 2021; Veling et al., 2013; but see Lawrence et al., 2015).

Although several accounts have been proposed to explain the NoGo-devaluation-effect (Veling, Chen, et al., 2017; Veling, Lawrence, et al., 2017), it is still unclear how to best explain how merely not responding leads to devaluation. In the present research, we will examine whether the strength of the stimulus-stop associations is related to the strength of the NoGo-devaluation-effect, because there are some indications in the literature suggesting that stopping tightly interacts with the Pavlovian aversive system (Verbruggen et al., 2014). Specifically, Verbruggen and colleagues (2014) have proposed a model (i.e. the architecture of the associative stop system) in which the stop and Go systems function as the instrumental equivalents of the Pavlovian aversive and appetitive systems. According to the model, hard-wired reciprocal excitatory connections between the stop and the aversive systems exist, and between the Go and the appetitive systems. Besides, the Pavlovian aversive and appetitive systems mutually inhibit each other. Thus, stopping itself may be innately aversive due to its tight interaction with the Pavlovian aversive system. This idea is consistent with other research on action-valence asymmetries (Guitart-Masip et al., 2012, 2014), which has uncovered a hard-wired Pavlovian bias during instrumental learning, such that participants learned NoGo responses better when they led to the avoidance of punishment compared to when they were rewarded.

Hence, stopping may induce negative affect due to its tight interaction with the Pavlovian aversive system (see Figure 1). This means that stronger stimulus-stop associations, could be related to a stronger NoGo-devaluation-effect. But how much evidence is there for the development of stimulus-stop associations during GNG?

The NoGo-RT-effect: evidence for developing stimulus-stop associations

There is evidence that GNG can influence motor responses (i.e. RTs) toward Go and NoGo stimuli after initial training. Verbruggen and Logan (2008) found first evidence for this by using a two-phase paradigm where the stimulus-action mappings (e.g. respond to large objects and not to small objects) were reversed after substantial training in a test phase. Although this work points to the possibility of the acquisition of stimulus-stop associations during GNG, it is important to point out that the go/no-go task employed in this work deviates from the GNG used in most work examining stimulus devaluation. That is because the Go and NoGo responses were made based on the content of the images (e.g. size of the object) instead of external cues (e.g. a low or high tone; e.g. Johannes et al., 2021), and because neutral instead of appetitive stimuli were used. The latter is important as NoGo devaluation appears to be stronger for the appetitive nature of stimuli is higher (Chen et al., 2016; Veling et al., 2008; but see Chen,

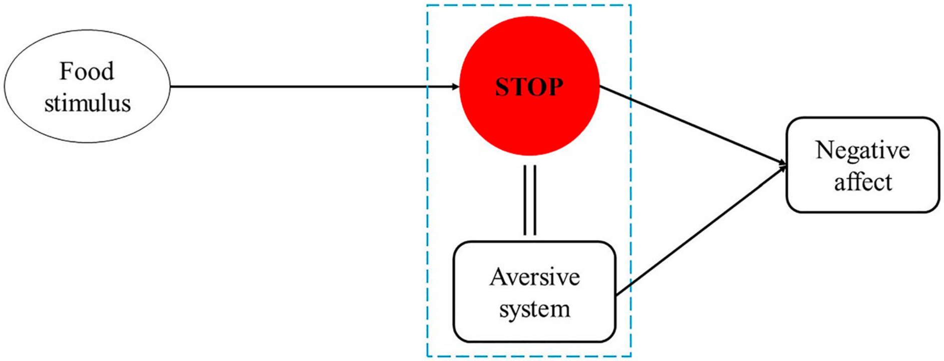

Figure 1. The relations between stopping and negative affect. (1) The black arrow represents stimulus-stop association. (2) The content within the dashed frame represents the tight interaction between the stopping and the Pavlovian aversive system.

Veling, De Vries, et al., 2018; Chen, Veling, Dijksterhuis, et al., 2018).

There is some work that examined the acquisition of stimulus-stop associations with external Go and NoGo cues presented near neutral stimuli. Specifically, Best and colleagues (2016) employed the two phase go/no-go task of Verbruggen and Logan (2008), but used external Go and NoGo cues instead of the content of the image to function as response cues. Thus, during the training phase, participants were trained to emit Go responses toward some stimuli that paired with external Go cues (Go stimuli), and withhold responses toward other stimuli that paired with external NoGo cues (NoGo stimuli). During the test phase, stimulus-action mappings were reversed for some stimuli by presenting Go cues with some former NoGo stimuli (NoGo_then_Go stimuli) and NoGo cues with some former Go stimuli (Go_then_NoGo_stimuli). Participants also emitted Go responses toward some former Go stimuli (Go_then_Go stimuli). Control stimuli were paired with both Go and NoGo responses across these two phases. Notice that Best et al. also added an expectancy rating before each trial to explore the role of expectancies in the acquisition of stimulus-action associations.

Results showed that in the test phase, the average RT for the NoGo_then_Go stimuli was larger than that for both of the Go_then_Go and control stimuli. We call this the *NoGo-RT-effect*. This effect suggests that people may form stimulus-stop associations during the training phase, thereby slowing down motor responses to the NoGo_then_Go stimuli even when the Go and NoGo cues are external and thus not part of the stimulus.

Although the Best et al. (2016), experiment revealed that stimulus-stop associations can develop during GNG with external Go and NoGo cues, it is important to note that their task still differed substantially from most work examining NoGo devaluation as they employed neutral stimuli, included control stimuli with inconsistent stimulus-response mappings, and included an expectancy rating before each trial. It is not known whether and how each of these factors has contributed to the development of the stimulus-stop associations, and hence whether stimulus-stop associations can also be found with a GNG as it is often implemented in more applied work (Stice et al., 2017).

Overview of experiments

The first goal of the present research is, therefore, to examine whether we could find evidence for the a NoGo-RT-effect, suggesting the acquisition of stimulus-stop associations, by employing a GNG including external Go/NoGo cues, consistent stimulus-response mappings, appetitive stimuli, and without expectancy ratings. The second goal of the present work is to examine how the NoGo-RT-effect may be related to the NoGo-devaluation-effect. We ran three experiments in which we aimed to measure these two effects within each experiment. In Experiment 1, we tried to measure these two effects within the same task. In Experiments 2 and 3, we measured them in separate tasks. Note that one challenge for the present research was that it was impossible to use a GNG that has been shown to elicit both the NoGo-devaluation-effect and the NoGo-RT-effect. Therefore, in Experiment 2 we employed a GNG that has been shown to elicit the NoGo-devaluation-effect (and we aimed to measure the NoGo-RT-effect with a novel procedure) and in Experiment 3 we employ a GNG that closely resembles work that found evidence for the NoGo-RT-effect (and we measured NoGo devaluation afterwards with an established task). Food stimuli were used as appetitive stimuli to connect this work to research applying GNG to promote healthy eating behaviour. Due to an error we failed to freeze the preregistration for Experiment 1. We uploaded hypotheses, materials, and strategy of analysis on the Open Science Framework (https://osf.io/tbr4x/). We successfully preregistered Experiments 2 (https://osf.io/nm25a/) and 3 (https://osf.io/vs3q7/) and the preregistrations include hypotheses, strategy of analysis, experimental materials (stimuli, scripts, etc.), raw and processed data, and R scripts for data analysis.

Experiment 1

In Experiment 1, we created a new evaluative task that enabled us to record both RTs and stimulus evaluations before and after the GNG. However, we failed to replicate the NoGo-devaluation-effect, nor did we find evidence for the NoGo-RT-effect. To reduce the length of this manuscript and to increase the readability, we decided to report Experiment 1 in online supplemental materials only (see S1 for more details).[2]

Experiment 2

In Experiment 2, participants first received a GNG. Afterwards we measured stimulus evaluations and RTs to the stimuli in two separate tasks in counterbalanced order. To assess the NoGo-devaluation-effect, we asked participants to rate the stimuli on a scale ranging from not at all attractive to very attractive both before and after GNG. This procedure is a reliable way to assess NoGo devaluation (Chen et al., 2016; Quandt et al., 2019), which means that NoGo stimuli decrease more in evaluation from pre to post measurement than both Go and untrained stimuli. For exploratory reasons the rating block was repeated three times. We expected to find a NoGo-devaluation-effect on the first rating block when the rating task was not preceded by the mouse-movement-task that measured the RT to the stimuli (as done in Experiment 1). This choice was made because we did not know whether and how repeated evaluations or the preceding mouse-movement-task would influence the NoGo-devaluation-effect. This allowed us to assess NoGo devaluation identical to previous work (Chen et al., 2016). We included three rating blocks to explore whether a rating of the NoGo stimulus would reduce the NoGo-devaluation-effect.

To measure RT to the stimuli, we asked participants to react to the stimuli as quickly as they could in a mouse-movement-task explained in detail below, and RT data from the first block were used for hypothesis testing only as motor movements in this speeded mouse-movement-task may, at least partly, undermine the training effects, and hence weaken effects on subsequent blocks. We still included the subsequent blocks so that we could examine this.

We preregistered the following hypotheses:

(1) Hypothesis 1 (NoGo-devaluation-effect): For evaluative ratings from the first rating block immediately after GNG, changes in food evaluation from before to after the GNG will be more negative for the NoGo stimuli than for both Go and untrained stimuli.
(2) Hypothesis 2 (NoGo-RT-effect): For reaction-times from the first block of the mouse-movement task, post-training action initiation will be larger for NoGo stimuli than both Go and untrained stimuli.

Method

Sample size

The planned sample size was 80 participants (40 in each counterbalancing condition), as previous work (Chen et al., 2016) showed that 30 participants were sufficient to detect the NoGo-devaluation-effect with the power of 80% immediately after the training.

Participants

Our recruitment resulted in eighty-five participants (slightly more than intended due to multiple online sign-ups for the final timeslot). According to our preregistered exclusion criteria (accuracy on either Go trials or NoGo trials is 3SD below the sample mean and below 90%) we excluded one participant. (18 males, 66 females, $M_{age} = 21.9$ years, $SD_{age} = 2.91$). See S2 for participant characteristics.

Materials

Ninety food pictures were selected as stimuli from the *food-pic database* (Blechert et al., 2019). We used the PsychoPy (Peirce, 2007) to program and implement the experimental tasks.

Procedure

The experiment included 7 successive tasks and Figure 2 visualises the main procedures. We counter-balanced the order between the post-training rating and mouse-movement-tasks, and the remaining tasks were presented in the order as described below.

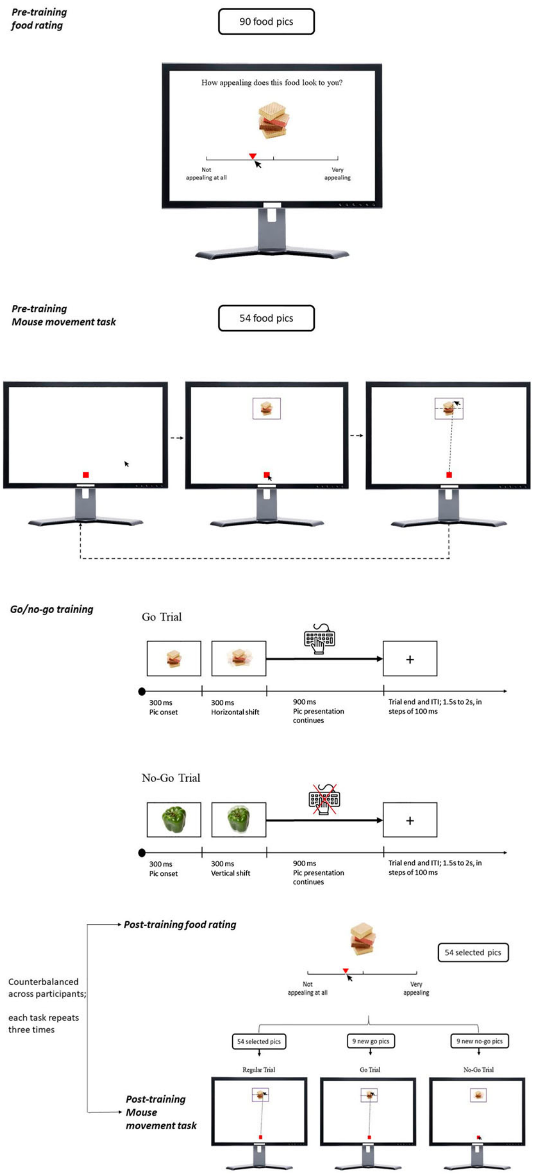

Figure 2. Diagram of main procedures in Experiment 2. (1) Pre-training food rating. (2) Pre-training mouse-movement-task. (3) Go/no-go training. (4) Post-training food rating and mouse-movement-tasks. The order of these two tasks were counterbalanced across participants and each task was repeated three times.

Pre-training food rating

The rating task was identical to our previous studies (Chen et al., 2016; Quandt et al., 2019). Participants rated all 90 food pictures on their perceived attractiveness. Each trial stared with a specific food picture presented at the centre of the screen, and participants were asked to rate this food picture on a 200-point scale (0 = *Not appealing at all*, 200 = *Very appealing*).

Item selection

After the pre-training rating, all of the 90 food pictures were ranked from the highest value to the lowest value per participant. Next, the 18 top-ranked and 18 bottom-ranked food pictures were removed, which left 54 medium-ranked food stimuli. These stimuli were further divided into 3 training conditions – Go/NoGo/untrained – with 18 in each condition and with approximately same average value for each condition.

Pre-training mouse movement task

Participants then performed a pre-training mouse-movement-task that we developed to attempt to capture the NoGo-RT-effect. Each trial started with a red square at the bottom of a blank screen, and participants were instructed to place the mouse cursor into the red square and wait. After a short delay (200 ms) a food picture appeared and participants needed to move the cursor as quickly as possible from the red square to this food picture. Upon the cursor above the middle part of the picture, this picture disappeared immediately and the current trial ended.

For the reaction-time measurement we focused on action initiation, namely the reaction-time the cursor stayed in the red square. Because the stimulus-stop associations can be triggered automatically and rapidly (Chiu et al., 2012), we reasoned that action initiation should be more sensitive when measuring stimulus-stop associations. Note that since the preregistered outcome variable was post-training action initiation, we did not record pre-training action initiation. The purpose was merely to acquaint participants with the task for all 54 selected stimuli.

GNG

Participants then performed a GNG that was similar to previous work (Quandt et al., 2019). Each trial started with the display of a food picture for 300 ms.

Afterwards, this picture shifted either vertically or horizontally for 300 ms, with one type of shift signalled a go response should be made and the other type signalled responding should be withheld. The Go and NoGo cues were counterbalanced across participants. Independent of the response, the food picture remained on screen for 1200 ms in total. The inter-trial interval randomly varied between 1.5 s and 2.5 s, in steps of 100 ms. The training comprised 8 blocks, with 18 Go trials and 18 NoGo trials randomly displayed once within each block, and Go stimuli were always paired with Go cues and NoGo stimuli always paired with NoGo cues.

Post-training food rating

After GNG, participants performed an identical rating task as before the GNG. Only the 54 selected pictures were displayed and participants performed this task three times.

Post-training mouse-movement-task

After GNG, participants also performed a post-training mouse-movement-task. This task was similar to its pre-training counterpart except for several modifications. To increase the probability of retrieving stimulus-stop associations, we embedded a *go/no-go setting* in this task (Best et al., 2016). Specifically, we included the 36 previously excluded high- and low-value stimuli. These stimuli were allocated to four sets each consisting of nine pictures. One set of pictures were paired with the same Go cues as in the GNG, and participants needed to emit Go responses toward these new Go pictures. One set of pictures were paired with the same NoGo cues as in the previous GNG and participants needed to withhold motor responses toward these new NoGo pictures. The remaining two sets of pictures were served as filler stimuli. Participants performed this task three times, and in each time there were 18 old and 9 new Go stimuli, 18 old and 9 new NoGo stimuli, 18 untrained and 18 filler stimuli.

Recognition task

In this task, all food pictures from the GNG were displayed again, and participants indicated for each picture whether they performed a Go or NoGo response during GNG (Figure 3).

Confirmatory analyses

Since we counterbalanced the order between post-training food rating and mouse-movement-tasks, we split our data into three datasets: the *evaluation-first dataset* that contained data from participants who first received the post-training food rating, the *motor-first dataset* that contained data from participants who first received the post-training mouse-movement-task, and *the full dataset*. Note that we performed confirmatory analyses for the devaluation hypothesis on the evaluation-first dataset and confirmatory analyses for the RT-effect on the full dataset.

We preregistered multilevel models under both Frequentist and Bayesian frameworks for all confirmatory analyses. Table 1 lists the model syntax. We only reported *p*-values in the main text for the sake of consistency with Experiment 1 (see S1), and to reduce the length of this manuscript. Results of Bayesian models can be found in S2.

Exploratory analyses

We also ran multilevel models under both Frequentist and Bayesian frameworks for the exploratory analyses. See S2 for details.

Results

Performance

For the GNG, the average Go accuracy was 98.92% ($SD = 2.82\%$) and the average NoGo accuracy was 98.93% ($SD = 1.59\%$). The average Go RT was 351 ms ($SD = 106$ ms). For the recognition task, the average accuracy for Go stimuli was 63.0% ($SD = 26.3\%$), and 77.4% ($SD = 22.7\%$) for NoGo stimuli.

Item selection check

For the evaluation-first dataset, we ran a repeated-measures ANOVA with condition (Go/NoGo/untrained) as the predictor variable and pre-training food evaluation as the outcome variable. The effect of condition was not significant, $F(2, 80) = 0.94$, $p = .40$, indicating successful matching of stimulus value before the training.

Confirmatory analyses

Hypothesis 1 (NoGo-devaluation-effect). The main effect of condition was significant, $F(2, 33.46) = 8.08$, $p < .01$. The descriptive statistics were respectively, Go, $M = 1.55$, $SD = 28.50$; NoGo, $M = -5.55$, $SD = 29.73$; untrained, $M = -0.28$, $SD = 28.18$. Follow-up pairwise comparisons showed that the difference score of NoGo stimuli was significantly lower than that of Go stimuli, $F(1, 35.65) = 13.91$, $p < .001$, and untrained stimuli, $F(1, 31.82) = 11.75$, $p < .01$. There was no

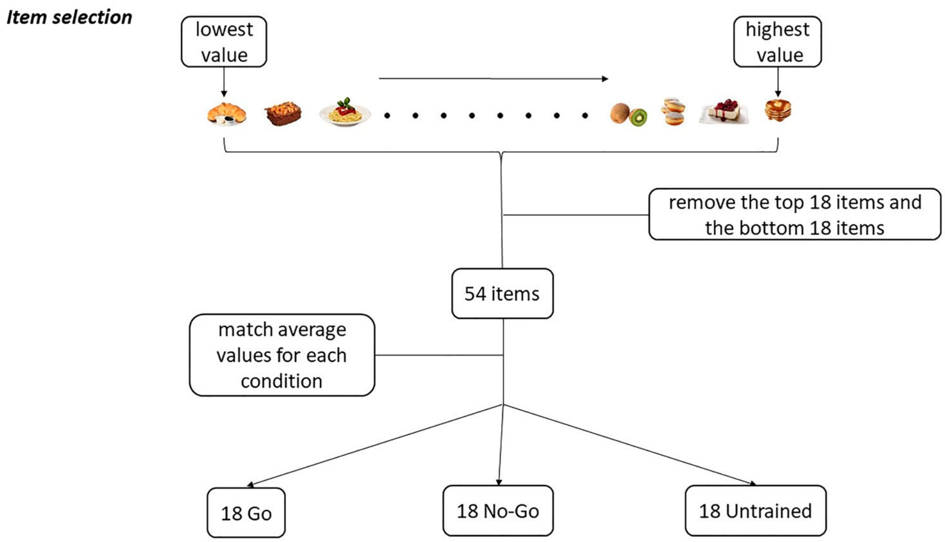

Figure 3. Item selection procedure.

significant difference between Go and untrained stimuli, $F(1, 35.17) = 1.12$, $p = .30$. These results were consistent with that of Bayesian models. Together, we replicated the NoGo devaluation-effect and Figure 4 (the far left panel) shows the results.[3]

Hypothesis 2 (NoGo-RT-effect). The main effect of condition was not significant, $F(2, 49.42) = 0.69$, $p = .51$. The descriptive statistics were respectively, Go, $M = 486$ ms, $SD = 214$ ms; NoGo, $M = 490$ ms, $SD = 192$ ms; untrained, $M = 484$ ms, $SD = 190$ ms. Follow-up pairwise comparisons showed that the difference between Go and NoGo stimuli was not significant, $F(1, 51.05) = 0.43$, $p = .52$. There was no significant difference between NoGo and untrained stimuli, $F(1, 46.74) = 1.71$, $p = .20$, and no significant difference between Go and untrained stimuli, $F(1, 47.67) = 0.16$, $p = .69$. These results were consistent with that of Bayesian models and Figure 5 (the far left panel) shows the results.

Table 1. Main multilevel models and *R* syntax in Experiment 2.

Model	*R* syntax
1	afex::mixed (value difference score ~ condition + (1 + condition | participant) + (1 + condition | stimulus))
2	afex::mixed (post-training action initiation ~ condition) + (1 + condition | participant) + (1 + condition | stimulus))

Note. In the codes above, condition has three levels: Go/NoGo/untrained; value difference score = post-training evaluation − pre-training evaluation; participant and stimulus are the grouping variables.

Exploratory analyses

The evaluation-first dataset. First, we examined whether there was a NoGo-devaluation-effect on the second and third blocks of evaluation. For each block, the main effect of condition was significant, and follow-up pairwise comparisons showed that the difference score for NoGo stimuli was significantly lower than both Go and untrained stimuli; there was no significant difference between Go and untrained stimuli. Furthermore, indications from *p*-values and 95% credible intervals were consistent with each other, providing further support for the devaluation-effect (Figure 4).

Second, we examined whether there was a NoGo-RT-effect across three blocks of action initiation. For each block, the main effect of condition was not significant, and all follow-up pairwise comparisons demonstrated non-significant differences. Furthermore, indications from *p*-values and 95% credible intervals were consistent with each other, providing no support for the RT-effect (Figure 5).

The motor-first dataset. Next, we examined whether there was a NoGo-devaluation-effect across three blocks of evaluation for participants whose ratings were collected after the mouse-movement-task. For each block, the main effect of condition was not significant, and all follow-up pairwise comparisons demonstrated non-significant differences except that the difference between Go and NoGo condition

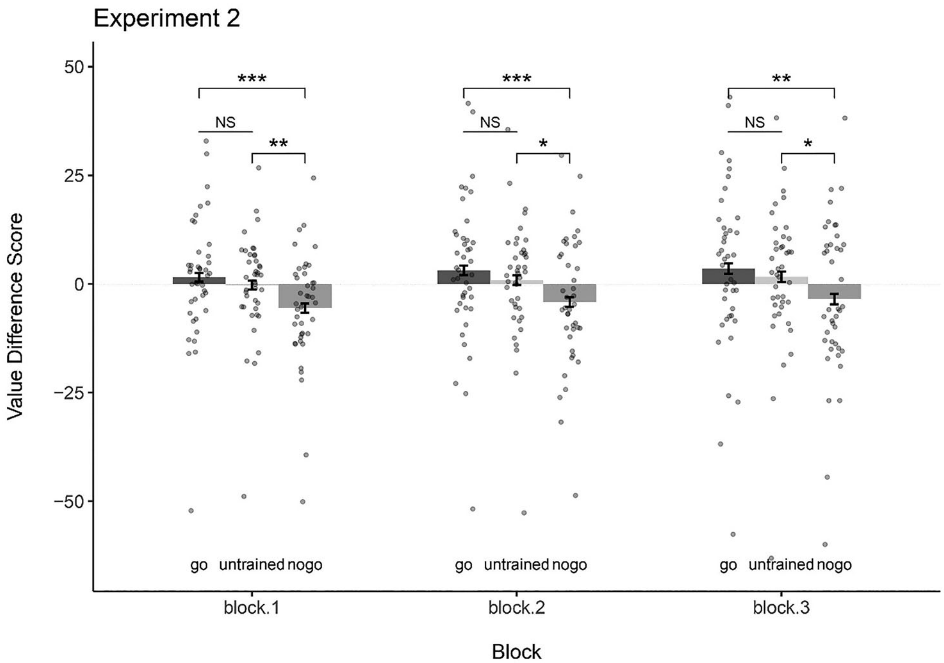

Figure 4. The effect of GNG on stimulus evaluation for 41 participants who first received the post-training food rating on each block. Dots represent mean value difference score per participant. Error bars represent the within-subject standard errors of mean. Block refers to the first, second, the third post-training block, respectively. Data from the first block were used for confirmatory analyses, and data from the second and third blocks were used for exploratory analyses. *$p < .05$; **$p < .01$; ***$p < .001$.

was significant on the first block. Furthermore, indications from p-values and 95% credible intervals were consistent with each other, providing no support for the devaluation-effect.

Then, we examined whether there was a NoGo-RT-effect for participants who received the mouse-movement-task before the rating task across three blocks of action initiation. For each block, the main effect of condition was not significant, and all follow-up pairwise comparisons demonstrated non-significant differences. Furthermore, indications from p-values and 95% credible intervals were consistent with each other, providing no support for the RT-effect.

The full dataset. We examined subsequently whether there was a NoGo-devaluation-effect across three blocks of evaluation when the counterbalancing conditions were collapsed. For each rating block (1, 2 and 3), the main effect of condition was significant, and follow-up pairwise comparisons showed that the difference score for NoGo stimuli was significantly lower than both Go and untrained stimuli; there was no consistent significant difference between Go and untrained stimuli, but the difference was significant in the first block. Furthermore, indications from p-values and 95% credible intervals were consistent with each other, providing further support for the consistency of the devaluation-effect.

Second, we examined whether there was a NoGo-RT-effect on the second and third block of action initiation (note this effect was already tested for the first block in the confirmatory analyses). For each block, the main effect of condition was not significant, and all follow-up pairwise comparisons demonstrated non-significant differences. Furthermore, indications from p-values and 95% credible intervals were consistent with each other, providing no support for the RT-effect.

Correlations between evaluation and action initiation scores. Although there was no NoGo-RT-effect, we still explored the relations between evaluative ratings and reaction-times using the full dataset. We first calculated average post-training scores of both evaluation and action initiation per condition. Next, for each contrast (i.e. Go–NoGo; NoGo–untrained; Go–untrained), we calculated a new difference score for evaluation and action initiation,

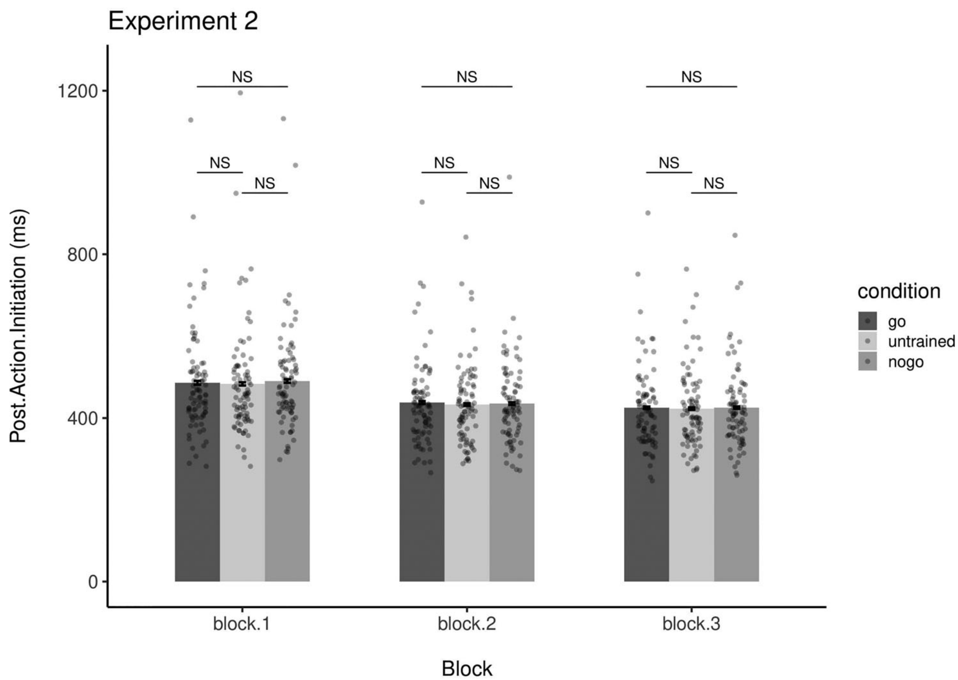

Figure 5. The effect of GNG on reaction-time for all 84 participants on each block. Dot represent mean post-training action initiation score per participant. Error bars represent the within-subject standard errors of mean. Block 1, 2, and 3 refers to the first, second, the third post-training block, respectively. Data from the first block were used for confirmatory analyses, and data from the second and third blocks were used for exploratory analyses. *$p < .05$; **$p < .01$; ***$p < .001$.

respectively. Finally, we examined the correlations between these new difference scores within each contrast. There was no significant correlation for each contrast. See Table 2 for details.

Discussion

In Experiment 2, we measured stimulus evaluation and RTs in two separate tasks. Results revealed a clear NoGo-devaluation-effect. We also observed two novel findings regarding the devaluation-effect. First, we counterbalanced the order between the post-training food rating and mouse-movement-tasks. Interestingly, the devaluation-effect disappeared for participants who first performed the mouse-movement-task, showing the devaluation-effect is diminished by executing simple speeded motor responses toward the stimuli. The fact that the devaluation-effect diminishes when stimuli are responded to after the training is understandable as the responses may undo the learned stimulus-stop associations. This finding is consistent with previous work that found that measuring the effect of GNG on food choice immediately after the training may weaken the effect of the training on a subsequent food choice task presented days later (Chen et al., 2021). The second new finding is that the devaluation-effect remained visible across repeated rating blocks, indicating that NoGo devaluation is not diminished by occasional evaluative responses to the (NoGo) stimuli. Thus, the NoGo-devaluation-effect does not survive three speeded responses as executed during the mouse-movement-task, but it does survive two evaluative rating responses. We return to this observation in the General discussion.

Table 2. Correlations between evaluative ratings and reaction-times for different difference scores in Experiment 2.

Contrast	*r*	*p*
Go–NoGo	.01	.38
Untrained–NoGo	.05	.74
Go–Untrained	−.01	.70

Importantly, in Experiment 2 we did not find a NoGo-RT-effect and no relations between evaluative ratings and RTs were found. To increase chances to capture the NoGo-RT-effect, we used a version of the GNG that required people to closely attend to the stimuli, embedded a *go/no-go setting* in the post-training mouse-movement-task, and used the post training RTs only. However, this did not result in the NoGo-RT-effect. This means that the NoGo-RT-effect either does not exist with the GNG employed, or that it is more difficult to capture the RT-effect compared to the devaluation-effect. However, one of the reviewers pointed out that our mouse-movement-task barely resembles the two-phase GNG paradigm in previous work (Best et al., 2016) that did capture the RT-effect. Therefore, the failure to obtain a NoGo-RT-effect may be due to some characteristics of the mouse-movement-task. Thus, we ran Experiment 3, in which we employed a two-phase GNG discussed in the introduction (Best et al., 2016), in a final attempt to capture both the NoGo-RT and NoGo-devaluation effect within a single experiment.

Experiment 3

In Experiment 3, we employed the Best et al. (2016) version two-phase GNG with some modifications on task characteristics described below. We preregistered two hypotheses for the NoGo-RT-effect consistent with Best et al.: The average RT in the test phase would be longer a) for the NoGo_then_Go stimuli than that of the Go_then_Go stimuli and b) for the NoGo_then_Go stimuli than the control_50%_Go stimuli.

We preregistered two hypotheses for the NoGo-devaluation-effect: Regarding the difference between the pre-and post-training evaluation scores (i.e. difference score = post-training score − pre-training score), the NoGo_then_NoGo stimuli would be lower than that of a) the Go_then_Go stimuli and b) the control stimuli, respectively.

Method

Sample size

We used the G*Power (version 3.1.9.2) to calculate the sample size based on the effect size of previous work (Experiment 4; Best et al., 2016). The power analyses revealed that we would need 40 participants. We planned to recruit 70 participants to account for the fact that effect sizes from published findings are often inflated, for example due to the publication bias (Anderson et al., 2016). We depicted the details for the power analyses in our preregistration documents.

Participants

Seventy participants at Radboud University were recruited. According to our preregistered exclusion criteria (same as Experiment 2) we excluded four participants, hence 66 participants were left for the analysis (20 males, 45 females, 1 non-binary M_{age} = 22.2 years, SD_{age} = 2.55). See S2 for participant characteristics.

Materials

Sixty food pictures were selected as stimuli from the *food-pic database* (Blechert et al., 2019). We used the PsychoPy (Peirce, 2007) to program and implement the experimental tasks.

Procedure

Three sequential tasks were included (see Figure 6). Note that the item selection procedure (panel B) and both pre-and post-training food rating tasks (panels A and D) were identical to that of Experiment 2.

GNG

This GNG included two sequential phases: the training phase and the test phase (see Table 3). The training phase included three stimuli types: the 12 Go stimuli that were paired with Go responses 100% of the time; the 12 NoGo stimuli that were paired with NoGo responses 100% of the time; the 12 control stimuli that were paired with Go and NoGo responses 50% of the time, in other words, these control stimuli were control_50%_Go stimuli during half of the training phase, whereas control_50%_NoGo stimuli during the other half.

The test phase included six stimuli types: Participants emitted Go responses toward half of the former Go stimuli (Go_then_Go stimuli) but withheld response to the other half (Go_then_NoGo stimuli); participants withheld responses toward half of the former NoGo stimuli (NoGo_then_NoGo stimuli), but emitted Go responses to the other half (NoGo_then_Go stimuli); participants both emitted Go responses and withheld responses toward the control stimuli 50% of the time (control_50%_Go and control_50%_NoGo stimuli).

Each trial started with displaying a specific food picture for 300 ms. Next, a blank screen was displayed for 900 ms, during this time window either an auditory Go or an auditory NoGo cue would be presented and participants gave either the Go response (press the "B" key) or the NoGo response (withhold any motor response) based on the specific cue. Each

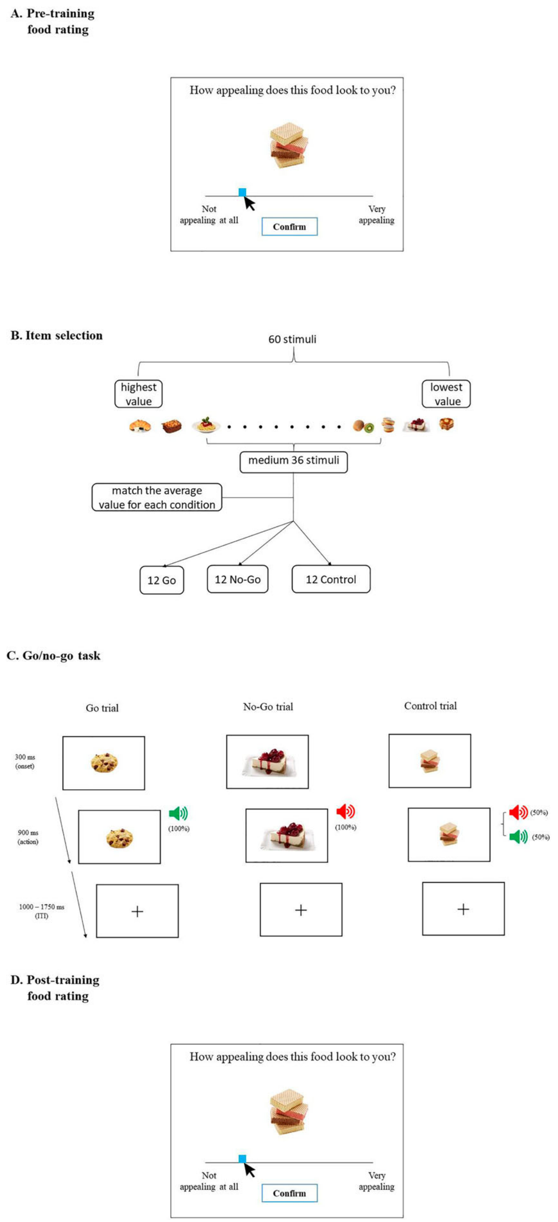

Figure 6. Procedure of Experiment 3. (1) Pre-training food rating. (2) Item selection. (3) Go/no-go training. (4) Post-training food rating.

type of the cue lased for 300 ms. Finally, a fixation cross was presented during the inter-trial-interval (ITI) phase (1000 to 1750 ms, in steps of 150 ms).

The training phase included 10 blocks, with 12 Go, 12 NoGo, and 12 control stimuli per block. The test phase included 2 blocks, with 6 Go_then_Go, 6 Go_then_NoGo, 6 NoGo_then_NoGo, 6 NoGo_then_Go, and 12 control stimuli per block.

Confirmatory analyses

For the RT data, we preregistered running paired-samples *t* tests to compare the NoGo_then_Go stimuli with Go_then_Go and control_50%_Go stimuli, in accordance with previous work (Best et al., 2016). For the evaluation data, we preregistered running paired-samples *t* tests to compare the NoGo_then_NoGo stimuli with Go_then_Go and

Table 3. Stimulus-cue contingency for the GNG in Experiment 3.

		Percentage of NoGo trials	
Stimuli type	No. of stimuli	Training phase	Test phase
Go	12	0	50
NoGo	12	100	50
Control	12	50	50

control stimuli, in line with our previous work (Chen et al., 2016).

Exploratory analyses

For the RT data, we ran a paired-samples *t* test to compare the Go_then_Go and control_50% Go stimuli; for the evaluation data, we ran a paired-samples *t* test to compare the Go_then_Go and control stimuli.

We also examined the correlations between the RT and evaluative data, to reduce the length of the manuscript, we put those details into the S2.

Results

Performance

For the training phase, the average Go accuracy was 99.09% ($SD = 1.94\%$) and the average NoGo accuracy was 98.78% ($SD = 1.20\%$), and the average Go RT was 362 ms ($SD = 109$ ms).

Item selection check

We ran a repeated-measures ANOVA with condition (Go/NoGo/control) as the predictor variable and pre-training food ratings as the outcome variable. The effect of condition was non-significant, $F(2, 130) = .80$, $p = .45$, indicating that all three conditions were matched on pre-training food rating.

Confirmatory analyses

Hypothesis 1 (NoGo-RT-effect). The descriptive statistics for the RTs per condition were respectively, Go_then_Go, $M = 357$ ms, $SD = 80.5$ ms; NoGo_then_Go, $M = 381$ ms, $SD = 84.0$ ms; control_50%_Go, $M = 367$ ms, $SD = 81.7$ ms. The average RT of the NoGo_then_Go stimuli was significantly larger than that of the Go_then_Go stimuli, $M_{diff} = .024$, $t(65) = 4.60$, $p < .001$, 95% CI [.014, .034], and also significantly larger than that of the control_50%_Go stimuli, $M_{diff} = .014$, $t(65) = 2.82$, $p < .01$, 95% CI [.004, .023]. So we replicated the NoGo-RT-effect and Figure 7 visualises these data.

Hypothesis 2 (NoGo-devaluation-effect). The descriptive statistics for the average ratings per condition were Go_then_Go, $M = 5.94$, $SD = 36.06$; NoGo_then_NoGo, $M = -.29$, $SD = 32.56$; control, $M = 1.77$, $SD = 33.88$. The difference score of the NoGo_then_NoGo stimuli was significantly lower than that of the Go_then_Go stimuli, $M_{diff} = -6.22$, $t(65) = -2.79$, $p < .01$, 95% CI [−10.69, −1.76]. However, there is no significant difference between the NoGo_then_NoGo and control stimuli, $M_{diff} = -2.05$, $t(65) = -1.33$, $p = .19$, 95% CI [−5.12, 1.02]. So we failed to replicate the NoGo-devaluation-effect and Figure 8 visualises these data.

Exploratory analyses

The average RT of the control_50%_Go stimuli was significantly larger than that of the Go_then_Go stimuli (Figure 7), $M_{diff} = .01$, $t(65) = 2.39$, $p < .05$, 95% CI [.002, .019]. This suggests that participants developed stronger stimulus-go associations with more training.

The difference score of the evaluative ratings of the control stimuli was significantly lower than that of the Go_then_Go stimuli (Figure 8), $M_{diff} = 4.17$, $t(65) = 2.13$, $p < .05$, 95% CI [.26, 8.09]. This suggests that go stimuli became more positive than control stimuli.

There were again no significant correlations between the RT and evaluative data, see S2 for details.

Discussion

In Experiment 3, we employed a two-phase GNG to measure the NoGo-RT-effect, as this paradigm has produced a significant RT-effect in previous work (Best et al., 2016). We also employed the identical way of measuring the devaluation-effect as in Experiment 2. For the RT data, results now show a NoGo-RT-effect in our confirmatory tests such that participants were slowest to respond to stimuli that they were trained not to respond to. Importantly, this finding extends previous work by Best et al., as the current experiment shows GNG can lead to effects on RTs without the expectancy rating before each trial that was used in the Best et al., work, and when appetitive stimuli are used. The RT data further indicate that participants also acquired stimulus-Go associations as the reaction times for Go_then_Go stimuli were shorter than that of the control stimuli.

Interestingly, in Experiment 3, we did not replicate the NoGo-devaluation-effect, but the data instead showed that evaluations of Go stimuli became more

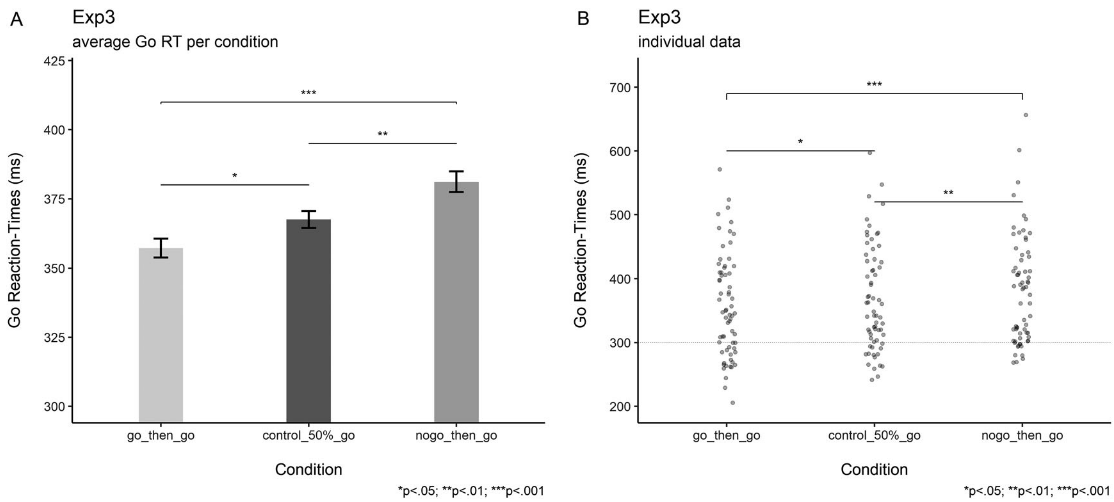

Figure 7. (A) The mean Go RT per condition. (B) The mean Go RT per condition per. *$p < .05$; **$p < .01$; ***$p < .001$.

positive from pre to post training compared to both the NoGo and control stimuli. The absence of this NoGo-devaluation-effect is striking as the power to detect this effect was high, and the changes from Experiment 2 to Experiment 3 were minimal. One explanation could be the inclusion of control stimuli in the GNG. These control stimuli may have clouded a clear distinction between Go and NoGo stimuli which may impact either the strength of the training or the effect of the training on the ratings. Because of an increased difficulty to distinguish Go from NoGo stimuli, participants may have attended more to the Go stimuli, as these are action relevant, leading to a Go-valuation-effect (Chen et al., 2016; Schonberg et al., 2014). We acknowledge this is speculative.

Furthermore, note that the RT data pattern can alternatively be viewed as a Go-RT-effect. That is, the more Go training people have received during GNG (i.e. Go_then_Go > control > NoGo_then_Go) the quicker they were during the test phase to react to these items. So, an alternative account for the findings of Experiment 3 is that people acquired stimulus-Go associations instead of stimulus-stop associations. This interpretation may also explain why we failed to obtain a NoGo-devaluation-effect.

Finally, no relations between evaluative ratings and RTs were found, suggesting that the Go-valuation-effect is not related to the strength of the RT-effect. Because of the interpretational difficulties outlined above we refrain from discussing the lack of this relation in more detail.

General discussion

The goal of the present work was to elicit the NoGo-RT and NoGo-devaluation-effects within the same experiment, in order to examine whether they are related. In Experiment 1, we did not replicate the NoGo-devaluation-effect, nor did we find the NoGo-RT-effect, when we employed a novel measurement procedure to capture both effects within the same task. Furthermore, there were no significant correlations between evaluation and action initiation. In Experiment 2, we examined these two effects in two separate tasks. We replicated the NoGo-devaluation-effect, and showed that this effect remained visible across multiple rating blocks. Interestingly, this devaluation-effect disappeared when participants performed the mouse-movement-task before the rating task. Furthermore, there were no significant correlations between evaluation and action initiation. In Experiment 3, we employed a two-phase GNG and we found the NoGo-RT-effect. However, this effect may also be interpreted as a Go-RT-effect. Besides, we did not obtain a NoGo-devaluation-effect, but we instead found a Go-valuation-effect, and no significant correlations between evaluation and action initiation. Thus, across three attempts, we failed to obtain both the NoGo-devaluation-effect and the NoGo-RT-effect within one experiment, and hence failed to meet our original goal. However, the experiments do provide interesting new insights into the possible nature of the NoGo-devaluation-effect.

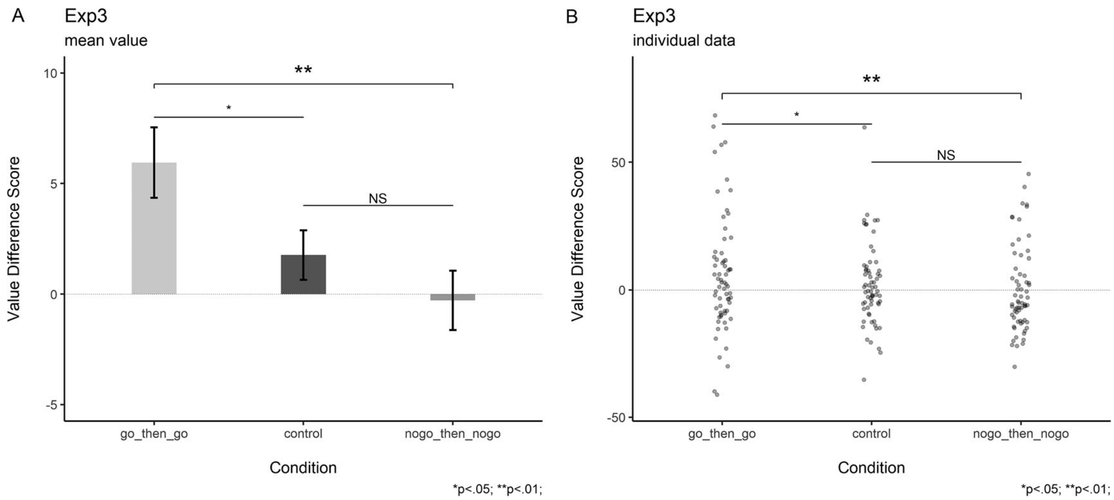

Figure 8. (A) The mean value difference score per condition. (B) The mean individual value difference score per condition. *$p < .05$; **$p < .01$.

Most important, the present findings suggest that the NoGo-devaluation-effect is both robust and fragile. The effect is robust because we replicated it when we employed the exact procedures used successfully and repeatedly before (e.g. Chen et al., 2016; Johannes et al., 2021), and because this effect remained visible across multiple rating blocks. In fact, Experiment 2 showed that the devaluation effect can at least survive two rating responses. However, the NoGo-devaluation-effect appears also fragile, because it disappeared when the rating scale was slightly adapted (Experiment 1), when people performed simple speeded motor mouse movements toward the stimuli before rating them (Experiment 2), and when a slightly different GNG paradigm was employed (Experiment 3).

Thus, the two-phase GNG (Best et al., 2016) is reliable in terms of capturing the NoGo-RT-effect but not the NoGo-devaluation-effect, whereas this is the other way around for the standard GNG (e.g. Chen et al., 2016). Therefore, we currently do not have a GNG paradigm that can capture both effects simultaneously. Together, these novel findings raise a number of theoretical and practical questions about the nature and applied value of the NoGo-devaluation-effect.

Theoretical implications

One interesting question is how the devaluation-effect can survive a couple of evaluative responses but not a couple of simple speeded mouse movements. One possibility is that the mouse-movement-task modified the stimulus-stop associations. It could be that participants developed stimulus-stop associations during the training, and that these associations were weakened or overridden by the subsequent speeded mouse movements, because such actions could be represented as *Go responses* and hence have interfered learned stimulus-stop associations (Chen et al., 2021) more so than the evaluative ratings did. According to this account, it may still be possible to assume that NoGo-devaluation is caused by stimulus-stop associations.

Alternatively, since stopping may be tightly associated with negative affect (Guitart-Masip et al., 2014; Verbruggen et al., 2014), it is possible that participants formed stimulus-negative-affect associations during GNG in Experiment 2 rather than stimulus-stop associations, as the relation between stopping and negative affect has been shown in different types of evidence. Clancy et al. (2019) provided physiological evidence (using facial electromyography) that negative affect is elicited immediately at the time when a motor-response is stopped (reflected by the engagement of the muscle corrugator supercilli during no-go trials), and the magnitude of this physiological index of negative affect predicted the level of devaluation measured in a subsequent rating task. Moreover, Doallo et al. (2012) provided neuroimaging evidence that brain activation associated with response suppression during a go/no-go task can predict behavioural data of devaluation in a subsequent rating task. This can explain why we failed to capture the

NoGo-RT-effect in Experiment 2, because stimulus-stop associations may not have been formed during GNG in the first place. Still, this raises the question why the devaluation-effect disappeared after the mouse-movement-task. Perhaps, the Go responses elicited some positive affect (Verbruggen et al., 2014) such that the stimulus-negative-affect associations were weakened by executing mouse movements. Previous studies showed that speeded Go responses appear to increase stimulus evaluations (Chen et al., 2016; Schonberg et al., 2014; Veling, Chen, et al., 2017; Veling, Lawrence, et al., 2017). This interpretation is also in line with the findings of Experiment 3 where we obtained both a Go-valuation-effect and found that participants' reaction times were quicker for stimuli that they were trained to respond to. Since the mouse-movement-task required high speed responses, it may have elicited some positive affect reducing the NoGo-devaluation-effect. According to this account, people may have acquired stimulus-Go associations in the present Experiment 3, but the NoGo-devaluation-effect in Experiment 2 may best be explained by stimulus-negative affect associations.

The second interesting question is the absence of devaluation-effect in the two-phase GNG paradigm (Experiment 3). As discussed earlier, this absence may be attributed to the use of the control stimuli, which may have blurred the distinction between Go and NoGo items. Furthermore, it could be that participants also devalued the control stimuli to some degree as a result of the 50% NoGo responses, thereby disguising the devaluation-effect (but see Jones et al., 2016). This explanation raises new questions for the role played by training characteristics in inducing the NoGo devaluation-effect.

The findings of Experiment 3 do raise the question why we did not find any effects on the RT measure in Experiment 2. One possibility is that that participants did develop the stimulus-Go and/or stimulus-stop associations during the training of Experiment 2, yet they did not retrieve them in the mouse-movement-task because of some task characteristics. Specifically, when measuring the NoGo-RT-effect, we employed the same reverse mapping rule (i.e. NoGo_then_Go) that has been used in in Experiment 3. However, we did not present the original Go and NoGo cues for old Go and NoGo stimuli as previous studies did (Best et al., 2016). Furthermore, the ratio was nine to one for Go and NoGo trials in the mouse-movement-task, whereas this ratio was one to one in previous studies (Best et al., 2016; Experiment 4). Perhaps these two task characteristics decreased the probability of retrieving the stimulus-stop associations during the mouse-movement-task. Importantly, when this is the case, it seems unlikely that stimulus-stop associations that were not retrieved during the mouse-movement-task did influence evaluations during the rating task.

Accordingly, the paradoxical conclusion based on the current findings is that NoGo-devaluation is not related to strength of stimulus-stop or stimulus-Go associations, but that the devaluation-effect can be diminished by executing speeded Go responses to the NoGo stimuli after GNG. Moreover, RT-effects can be obtained toward Go or NoGo stimuli, but the procedure that is needed to uncover such effects (Experiment 3) appears to not meet conditions needed to uncover the devaluation-effect.

Questions and implications for application

The GNG has been shown to change behaviour such as influencing eating and drinking behaviour (Lawrence et al., 2015; Oomen et al., 2018; Porter et al., 2018), and also smartphone app use (Johannes et al., 2021). This behaviour change has been shown to be partly mediated by stimulus devaluation (Johannes et al., 2021; Veling et al., 2013). Thus, from an applied perspective it is noteworthy that in Experiment 1 the devaluation-effect was not found when participants needed to respond quickly in the rating task. This finding is consistent with a recent meta-analysis, which shows that measuring devaluation by using a speeded response task is unreliable (Jones et al., 2016). The reason could be that stimulus evaluation, analogous to other types of value-based decision-making, requires individuals to sample evidence until reaching a decision threshold (Fisher, 2017). Hence measuring devaluation under strict time pressure may interrupt this sampling process and cause less robust and unstable effects on evaluation. From this perspective, one would expect GNG to influence people's behaviour particularly when people take time to make a decision. However, note that it has also been shown that GNG influences value-based choices particularly when people make fast choices (1500 ms; Chen et al., 2019). Thus, an important question for future research is to examine what kind of everyday life decisions can be influenced by GNG.

Second, the devaluation-effect seems vulnerable to simple speeded motor responses. This may be because the GNG on average lasts for 15 minutes, leaving these associations susceptible to other forms of Go responses. Based on this, future studies may investigate how to strengthen the NoGo-devaluation-effect, perhaps by creating more meaningful stimulus-response mappings during the training (Serfas et al., 2017), or by reinforcing stimulus-response contingencies (Guitart-Masip et al., 2014).

Third, from an applied perspective, one should employ consistent stimulus-response mappings to make sure that participants can develop clear and stable stimulus-response associations. In other words, pairing specific stimuli with either Go or NoGo responses 100% of the time.

Limitations and future directions

This study has several limitations**.** First, we measured devaluation via comparing changes in stimulus evaluation from before to after the GNG, but this procedure cannot allow us to investigate the process that generates devaluation. Future research may directly record affective responses toward stimuli at the trial level during GNG using some psychophysiological measures (Elkins-Brown et al., 2016). Furthermore, we measured stimulus-stop associations toward stimuli via reaction-times, but this index can only provide indirect evidence, and future research can employ more direct measures such as measuring the lateralised readiness potential in the EEG/ERP (Chiu et al., 2012).

Conclusion

In sum, our results suggest that GNG modifies evaluative and motor responses to stimuli, but still more work is needed to understand how these effects are related.

Notes

1. Note that in addition to associative learning, there are theories (Van Dessel et al., 2019) pointing to the possibility that participants form *propositions* about specific stimulus-response contingencies. However, the current research did not aim to disentangle them, and for the sake of simplicity we use the term *association*.
2. The wording of the evaluation question contained a grammatical error in Experiment 1 but not in Experiment 2 (the original sentence was "How attractive this food looks to you?"). We corrected this error in the figure for the sake of presentation.
3. We initially preregistered post-hoc comparisons if the main effect of training condition reached significance. However, since we had clear predictions for all pairwise comparisons, planned pairwise comparisons are more suitable for the confirmatory analyses.

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References

Adams, R. C., Lawrence, N. S., Verbruggen, F., & Chambers, C. D. (2017). Training response inhibition to reduce food consumption: Mechanisms, stimulus specificity and appropriate training protocols. *Appetite*, *109*, 11–23. https://doi.org/10.1016/j.appet.2016.11.014

Anderson, C. J., Bahník, Š, Barnett-Cowan, M., Bosco, F. A., Chandler, J., Chartier, C. R., & Zuni, K. (2016). Response to comment on "estimating the reproducibility of psychological science". *Science*, *351*(6277), 1037–1037. doi:10.1126/science.aad9163

Best, M., Lawrence, N. S., Logan, G. D., McLaren, I. P., & Verbruggen, F. (2016). Should I stop or should I go? The role of associations and expectancies. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(1), 115–137. https://doi.org/10.1038/nrn.2015.16

Blechert, J., Lender, A., Polk, S., Busch, N. A., & Ohla, K. (2019). Food-Pics_Extended – An image database for experimental research on eating and appetite: Additional images, normative ratings and an updated review. *Frontiers in Psychology*, *10*(March), 1–9. https://doi.org/10.3389/fpsyg.2019.00307

Chen, Z., Holland, R. W., Quandt, J., Dijksterhuis, A., & Veling, H. (2019). When mere action versus inaction leads to robust preference change. *Journal of Personality and Social Psychology*, *117*(4), 721–740. https://doi.org/10.1037/pspa0000158

Chen, Z., Holland, R. W., Quandt, J., Dijksterhuis, A., & Veling, H. (2021). How preference change induced by mere actionversus inaction persists over time. *Judgment and Decision-Making*, *16*(1), 201–237.

Chen, Z., Veling, H., De Vries, S. P., Bijvank, B. O., Janssen, I. M. C., Dijksterhuis, A., & Holland, R. W. (2018). Go/No-Go training changes food evaluation in both morbidly obese and normal-weight individuals. *Journal of Consulting and Clinical*

Psychology, *86*(12), 980–990. https://doi.org/10.1037/ccp0000320
Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2016). How does not responding to appetitive stimuli cause devaluation: Evaluative conditioning or response inhibition? *Journal of Experimental Psychology: General*, *145*(12), 1687–1701. https://doi.org/10.1037/xge0000236
Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2018). Do impulsive individuals benefit more from food Go/no-Go training? Testing the role of inhibition capacity in the no-Go devaluation-effect. *Appetite*, *124*, 99–110. https://doi.org/10.1016/j.appet.2017.04.024
Chiu, Y. C., Aron, A. R., & Verbruggen, F. (2012). Response suppression by automatic retrieval of stimulus-stop association: Evidence from transcranial magnetic stimulation. *Journal of Cognitive Neuroscience*, *24*(9), 1908–1918. https://doi.org/10.1162/jocn_a_00247
Clancy, E. M., Fiacconi, C. M., & Fenske, M. J. (2019). Response inhibition immediately elicits negative affect and devalues associated stimuli: Evidence from facial electromyography. *Progress in Brain Research*, *247*, 169–191. https://doi.org/10.1016/bs.pbr.2019.03.019
Custers, R., & Aarts, H. (2010). The unconscious will: How the. *Science*, *329*(July), 47–51. https://doi.org/10.1126/science.1188595
Di Lemma, L. C. G., & Field, M. (2017). Cue avoidance training and inhibitory control training for the reduction of alcohol consumption: A comparison of effectiveness and investigation of their mechanisms of action. *Psychopharmacology*, *234*(16), 2489–2498. https://doi.org/10.1007/s00213-017-4639-0
Doallo, S., Raymond, J. E., Shapiro, K. L., Kiss, M., Eimer, M., & Nobre, A. C. (2012). Response inhibition results in the emotional devaluation of faces: Neural correlates as revealed by fMRI. *Social Cognitive and Affective Neuroscience*, *7*(6), 649–659. doi:10.1093/scan/nsr031
Elkins-Brown, N., Saunders, B., & Inzlicht, M. (2016). Error-related electromyographic activity over the corrugator supercilii is associated with neural performance monitoring. *Psychophysiology*, *53*(2), 159–170. https://doi.org/10.1111/psyp.12556
Ferrey, A. E., Frischen, A., & Fenske, M. J. (2012). Hot or not: Response inhibition reduces the hedonic value and motivational incentive of sexual stimuli. *Frontiers in Psychology*, *3*(DEC), 1–7. https://doi.org/10.3389/fpsyg.2012.00575
Fisher, G. (2017). An attentional drift diffusion model over binary-attribute choice. *Cognition*, *168*, 34–45. https://doi.org/10.1016/j.cognition.2017.06.007
Frischen, A., Ferrey, A. E., Burt, D. H. R., Pistchik, M., & Fenske, M. J. (2012). The affective consequences of cognitive inhibition: Devaluation or neutralization? *Journal of Experimental Psychology: Human Perception and Performance*, *38*(1), 169–179. https://doi.org/10.1037/a0025981
Guitart-Masip, M., Duzel, E., Dolan, R., & Dayan, P. (2014). Action versus valence in decision making. *Trends in Cognitive Sciences*, *18*(4), 194–202. https://doi.org/10.1016/j.tics.2014.01.003
Guitart-Masip, M., Huys, Q. J. M., Fuentemilla, L., Dayan, P., Duzel, E., & Dolan, R. J. (2012). Go and no-Go learning in reward and punishment: Interactions between affect and effect. *NeuroImage*, *62*(1), 154–166. https://doi.org/10.1016/j.neuroimage.2012.04.024
Houben, K., & Giesen, J. C. A. H. (2018). Will work less for food: Go/No-Go training decreases the reinforcing value of high-caloric food. *Appetite*, *130*(August), 79–83. https://doi.org/10.1016/j.appet.2018.08.002
Houben, K., Havermans, R. C., Nederkoorn, C., & Jansen, A. (2012). Beer à no-Go: Learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction*, *107*(7), 1280–1287. https://doi.org/10.1111/j.1360-0443.2012.03827.x
Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite*, *56*(2), 345–349. https://doi.org/10.1016/j.appet.2010.12.017
Houben, K., Nederkoorn, C., Wiers, R. W., & Jansen, A. (2011). Resisting temptation: Decreasing alcohol-related affect and drinking behavior by training response inhibition. *Drug and Alcohol Dependence*, *116*(1-3), 132–136. https://doi.org/10.1016/j.drugalcdep.2010.12.011
Johannes, N., Buijzen, M., & Veling, H. (2021). Beyond inhibitory control training: Inactions and actions influence smartphone app use through changes in explicit liking. *Journal of Experimental Psychology: General*, *150*(3), 431. https://doi.org/10.1037/xge0000888
Jones, A., Di Lemma, L. C. G., Robinson, E., Christiansen, P., Nolan, S., Tudur-Smith, C., & Field, M. (2016). Inhibitory control training for appetitive behaviour change: A meta-analytic investigation of mechanisms of action and moderators of effectiveness. *Appetite*, *97*, 16–28. https://doi.org/10.1016/j.appet.2015.11.013
Kiss, M., Raymond, J. E., Westoby, N., Nobre, A. C., & Eimer, M. (2008). Response inhibition is linked to emotional devaluation: Behavioural and electrophysiological evidence. *Frontiers in Human Neuroscience*, *2*(OCT), 1–9. https://doi.org/10.3389/neuro.09.013.2008
Lawrence, N. S., O'Sullivan, J., Parslow, D., Javaid, M., Adams, R. C., Chambers, C. D., Kos, K., & Verbruggen, F. (2015). Training response inhibition to food is associated with weight loss and reduced energy intake. *Appetite*, *95*, 17–28. https://doi.org/10.1016/j.appet.2015.06.009
Murphy, R. A., & Honey, R. C. (2015). The Wiley handbook on the cognitive neuroscience of learning. In *The Wiley handbook on the cognitive neuroscience of learning*. https://doi.org/10.1002/9781118650813.
Oomen, D., Grol, M., Spronk, D., Booth, C., & Fox, E. (2018). Beating uncontrolled eating: Training inhibitory control to reduce food intake and food cue sensitivity. *Appetite*, *131*(August), 73–83. https://doi.org/10.1016/j.appet.2018.09.007
Peirce, J. W. (2007). PsychoPy-Psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1–2), 8–13. https://doi.org/10.1016/j.jneumeth.2006.11.017
Porter, L., Bailey-Jones, C., Priudokaite, G., Allen, S., Wood, K., Stiles, K., Parvin, O., Javaid, M., Verbruggen, F., & Lawrence, N. S. (2018). From cookies to carrots: The effect of inhibitory control training on children's snack selections. *Appetite*, *124*, 111–123. https://doi.org/10.1016/j.appet.2017.05.010
Quandt, J., Holland, R. W., Chen, Z., & Veling, H. (2019). The role of attention in explaining the no-Go devaluation-effect: Effects on appetitive food items. *Journal of Experimental Psychology: Human Perception and Performance*, *45*(8), 1119–1133. https://doi.org/10.1037/xhp0000659

Scholten, H., Granic, I., Chen, Z., Veling, H., & Luijten, M. (2019). Do smokers devaluate smoking cues after Go/no-Go training? *Psychology and Health*, *34*(5), 609–625. https://doi.org/10.1080/08870446.2018.1554184

Schonberg, T., Bakkour, A., Hover, A. M., Mumford, J. A., Nagar, L., Perez, J., & Poldrack, R. A. (2014). Changing value through cued approach: An automatic mechanism of behavior change. *Nature Neuroscience*, *17*(4), 625–630. https://doi.org/10.1038/nn.3673

Serfas, B. G., Florack, A., Büttner, O. B., & Voegeding, T. (2017). What does it take for sour grapes to remain sour? Persistent effects of behavioral inhibition in Go/no-Go tasks on the evaluation of appetitive stimuli. *Motivation Science*, *3*(1), 1–18. https://doi.org/10.1037/mot0000051

Stice, E., Yokum, S., Veling, H., Kemps, E., & Lawrence, N. S. (2017). Pilot test of a novel food response and attention training treatment for obesity: Brain imaging data suggest actions shape valuation. *Behaviour Research and Therapy*, *94*, 60–70.

Turton, R., BruideGom, K., Cardi, V., Hirsch, C. R., & Treasure, J. (2016). Novel methods to help develop healthier eating habits for eating and weight disorders: A systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews*, *61*, 132–155. https://doi.org/10.1016/j.neubiorev.2015.12.008

Van Dessel, P., Hughes, S., & De Houwer, J. (2019). How do actions influence attitudes? An inferential account of the impact of action performance on stimulus evaluation. *Personality and Social Psychology Review*, *23*(3), 267–284. https://doi.org/10.1177/1088868318795730

Veling, H., Aarts, H., & Stroebe, W. (2013). Stop signals decrease choices for palatable foods through decreased food evaluation. *Frontiers in Psychology*, *4*(NOV), 1–7. https://doi.org/10.3389/fpsyg.2013.00875

Veling, H., Chen, Z., Tombrock, M. C., Verpaalen, I. A. M., Schmitz, L. I., Dijksterhuis, A., & Holland, R. W. (2017). Training impulsive choices for healthy and sustainable food. *Journal of Experimental Psychology: Applied*, *23*(2), 204–215. https://doi.org/10.1037/xap0000112

Veling, H., Holland, R. W., & van Knippenberg, A. (2008). When approach motivation and behavioral inhibition collide: Behavior regulation through stimulus devaluation. *Journal of Experimental Social Psychology*, *44*(4), 1013–1019. https://doi.org/10.1016/j.jesp.2008.03.004

Veling, H., Lawrence, N. S., Chen, Z., van Koningsbruggen, G. M., & Holland, R. W. (2017). What is trained during food Go/No-Go training? A review focusing on mechanisms and a research agenda. *Current Addiction Reports*, *4*(1), 35–41. https://doi.org/10.1007/s40429-017-0131-5

Verbruggen, F., Best, M., Bowditch, W. A., Stevens, T., & McLaren, I. P. L. (2014). The inhibitory control reflex. *Neuropsychologia*, *65*(312445), 263–278. https://doi.org/10.1016/j.neuropsychologia.2014.08.014

Verbruggen, F., & Logan, G. D. (2008). Automatic and controlled response inhibition: Associative learning in the Go/No-Go and stop-signal paradigms. *Journal of Experimental Psychology: General*, *137*(4), 649–672. https://doi.org/10.1037/a0013170

Watson, P., Wiers, R. W., Hommel, B., & De Wit, S. (2014). Working for food you don't desire. Cues interfere with goal-directed food-seeking. *Appetite*, *79*, 139–148. https://doi.org/10.1016/j.appet.2014.04.005