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Disentangling go/no-go from motivational orientation to foods: Approaching is more than just responding

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ABSTRACT

Background: Training motor responses to food images can influence subsequent evaluations of the food and even consumption. One important question in the literature is whether training people to approach versus avoid food items is different from training people to respond ('go') versus not responding ('no go') to food items. Therefore, we systematically investigated whether mere action, i.e., withholding responses vs go responses, and motivational orientation, i.e., approach and avoidance, differentially change stimulus valence.
Methods: In 60 healthy participants, we contrasted approach, avoidance, and non-responses with the same neutral go response in their potential to change food liking ratings and affective facial responses.
Results: Training approach responses to stimuli increased their valence compared to mere go responses to stimuli as was evident from explicit liking ratings and facial corrugator activity. Unexpectedly, not responding to stimuli or avoiding stimuli did not decrease their valence relative to go stimuli.
Conclusion: The current results suggest that approach responses may be more effective to increase the valence of food items than mere go responses. They further suggest that the devaluation of non-responded stimuli that is often found in the literature may not become visible in the current task set-up where the Go/No-go training is administered on a touchscreen.

1. Introduction

Stimulus-response trainings, such as the Approach-Avoidance (AAT) or the Go/No-go training (GNG), hold promise in supporting people that try to break their unhealthy consumption pattens. Instead of targeting deliberate cognitive processes, for example by teaching individuals how to form goals or how to self-monitor their behavior, the AAT and GNG try to influence how someone perceives, or automatically reacts to food-related cues by repeatedly pairing food stimuli with motoric responses. In the AAT, participants usually approach images of neutral or healthy food and avoid images of unhealthy foods and in the GNG participants usually respond to neutral or healthy foods by pressing a button and withhold responses to unhealthy foods.

According to three recent *meta*-analyses (Allom, Mullan, & Hagger, 2016; Aulbach, Knittle, & Haukkala, 2019; Yang et al., 2019), the GNG can indeed affect food intake: participants eat less in ostensible taste tests which were usually conducted immediately after the GNG, and they report lower food intake on questionnaires which were usually completed at a later time point (Allom et al., 2016). Contrary to these quite robust effects of the GNG on eating behavior, AATs did not consistently reduce food intake (Aulbach et al., 2019; Yang et al., 2019). Instead, they changed *implicit* biases to food-related cues (Aulbach et al., 2019), an effect that is not due to publication bias according to recent *P*-curve analyses (Navas, Verdejo-Garcia, & Vadillo, 2021). Across various stimulus–response trainings, such implicit biases are proposed to mediate the effects of stimulus–response trainings on food intake (Aulbach et al., 2019; Strack & Deutsch, 2006), and in AATs studies – where they are called approach biases – they are related to food intake when regulatory capacities are low or depleted by characteristics of the situation (Kakoschke, Kemps, & Tiggemann, 2015, 2017b) (but see Becker, Jostmann, Wiers, & Holland, 2015). Thus, while both stimulus–response trainings may in principle affect food intake, distinct underlying mechanisms may make them more or less effective depending on the context.

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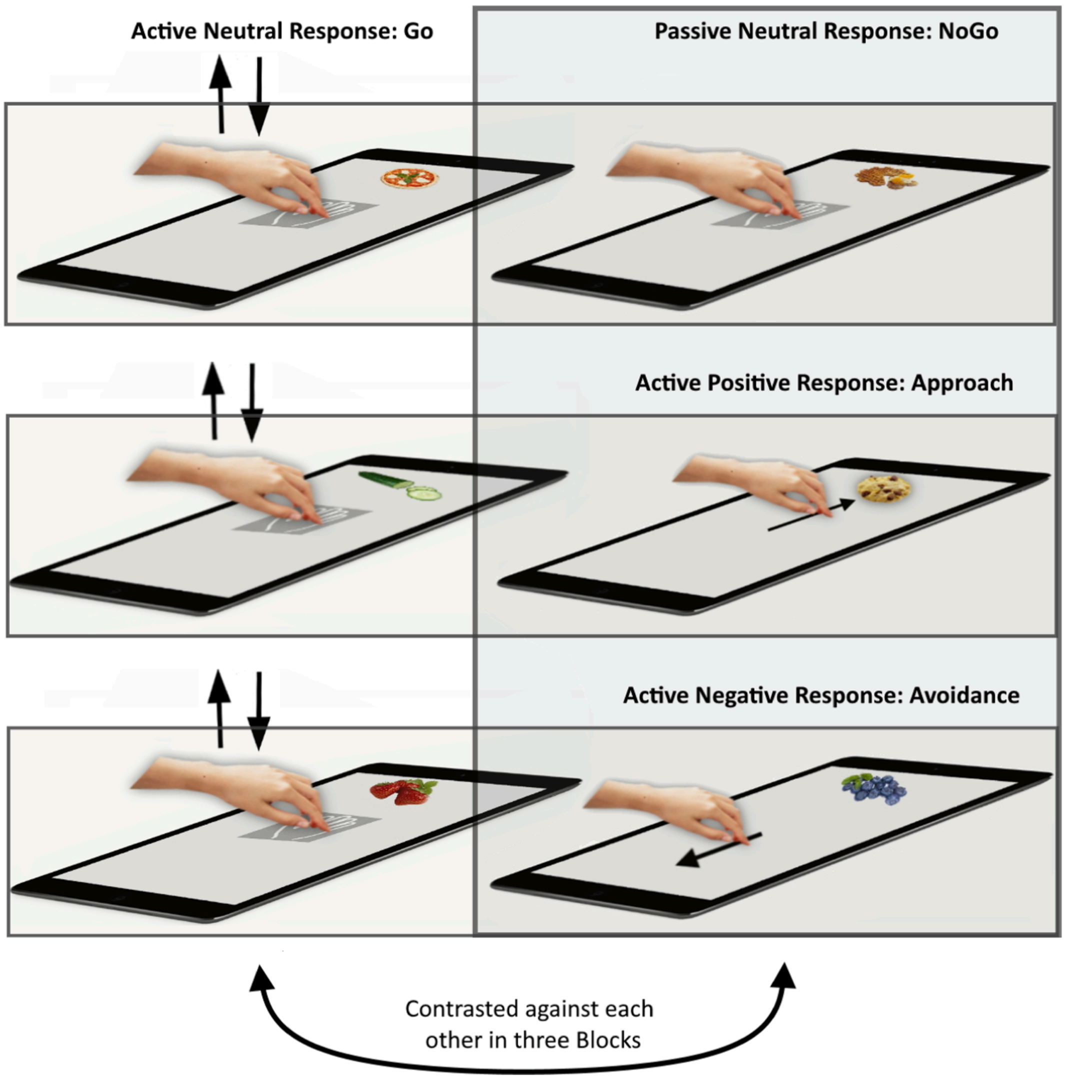

Fig. 1. Responses in the AAT-GNG task. Note. 'Go' is always the reference movement.

Next to regulatory capacities moderating the effects on food intake of the AAT, but not of the GNG (Chen, Veling, Dijksterhuis, & Holland, 2018; Kakoschke et al., 2017b), a direct comparison between the AAT and GNG (Kakoschke, Kemps, & Tiggemann, 2017a) indicated that the seemingly stronger reduction on food intake after the GNG may be also due to different experimental protocols. In this study (Kakoschke et al., 2017a), the GNG did not reduce unhealthy food intake when it was followed by an implicit bias measure, as it is common practice in AAT research. Furthermore, the AAT affected food choices stronger than the GNG, but conclusions should be handled with care as training tasks differed in trial length, and consistency of picture-response mapping. Indeed, the only systematic comparison study so far in the domain of eating behavior indicated that both trainings can have comparable effects on the proportion of choices for responded/approached vs non-responded/avoided foods when task characteristics are kept consistent between trainings (Veling et al., 2021). In the alcohol domain, another study comparing the AAT with the GNG (Di Lemma & Field, 2017) found comparable reductions in alcohol intake after each training type. This suggests that the higher effectiveness for GNG in recent *meta*-analyses may be due to varying experimental protocols, and that approach and avoidance affect stimulus valence and substance intake to a similar extent as mere active and passive responses in the GNG.

Comparable effect sizes after the AAT and GNG do however not necessarily imply that training effects are based on the same mechanism. While the AAT involves two active responses (i.e., approach and avoidance), previous studies highlight that changes in food choices after the GNG are mainly due to non-responses. Specifically, by comparing non-responded foods to both responded ones and untrained food pictures, a series of five experiments showed that non-responded foods decrease in liking relative to the responded *and* relative to untrained ones (Chen, Holland, Quandt, Dijksterhuis, & Veling, 2019; Chen, Veling, Dijksterhuis, & Holland, 2016). Together with the fact that this devaluation is present in GNG tasks which do not enforce prepotent responses (i.e., by using an equal number of go and no-go trials and a fixed interval between stimulus and no-go signal) and that the GNG does not improve markers of inhibitory control (e.g., N2 amplitude, stop-signal reaction time, inferior frontal gyrus activity), there is good reason to assume that changes in food intake after the GNG are specifically due to this devaluation and not due to trained inhibitory control as described by other prominent accounts (Veling, Becker, Liu, Quandt, & Holland, 2022). This devaluation of non-responded stimuli is often explained by the Behavior Stimulus Interaction (BSI) theory (Veling, Holland, & van Knippenberg, 2008). It assumes that stimuli are devaluated to resolve the conflict which occurs when a task requires non-responses to stimuli that trigger strong approach reactions such as foods (Veling et al., 2008), which is supported by the stronger devaluation for initially higher than lower rated foods in some studies (Chen et al., 2016; Veling et al., 2021, but see Chen et al., 2019; Chen et al., 2018). Non-responses to appetitive food items may cause a strong conflict due to the inter-dependence between the two axes of behavior control, namely the valence-axis running from reward to punishment and the action-axis running from vigor to inaction/inhibition: while in principle someone might act or inhibit a response to gain a reward or to avoid a punishment, it is easier to learn and execute active responses to attain rewards whereas it is easier to withhold behavior to avoid losses (Guitart-Masip et al., 2012).

The AAT does not entail non-responses. Yet, the likelihood to execute approach or avoidance to gain a reward or to avoid a punishment oppose each other by definition and clear compatibility effects (i.e. faster approach than avoidance for positive stimuli and faster avoidance than approach for negative ones) suggest that the ultimate action goal (approach or avoidance) is associated with stimulus valence (Phaf, Mohr, Rotteveel, & Wicherts, 2014). This is probably the case for approach *and* avoidance as positive stimuli specifically speed up approach and negative stimuli specifically speed up avoidance (rather than just impairing approach, which would give rise to compatibility effects as well; Kahveci, Van Alebeek, Berking, & Blechert, 2021; Van Alebeek, Kahveci, Rinck, & Blechert, 2023). Thus, similar to non-responses, avoidance of reward-related foods may cause a conflict and stimulus devaluation, because of its association with negative valence. In contrast, approach should not affect stimulus valence because approaching reward-related foods does not cause a conflict.

Yet, so far there are no studies investigating the effects of approach or avoidance on stimulus valence separately and different theories have been used to explain training effects of AAT: motivational theories assume a bidirectional relationship between stimulus valence and motivational systems (Neumann, Förster, & Strack, 2003), inferential accounts propose that participants infer their stimulus liking based on their actions (Van Dessel, Eder, & Hughes, 2018), and the common-coding account assumes that negative affect codes of avoidance movements or positive affect codes of approach movements bind to the feature codes of the stimulus (Eder & Rothermund, 2008). The former theory is not easily applicable to the active and passive responses in the GNG, but the latter two accounts would predict that clearly positively or negatively perceived actions such as approach and avoidance cause stronger changes in stimulus liking than mere active and passive responses without a clear action goal.

To gain new insight into the possible differences in how GNG and AAT affect responses to food, the current study is the first to systematically compare if non-responses cause a stronger decrease in valence than any action, or if the functional goal of an action, in the sense of distance change towards or away from stimuli, is relevant to change stimulus valence. To this end, we developed a combined AAT-GNG task: Approach, avoidance and non-responses were contrasted against the same go-response. The contrast between the go- and the non-responses (upper horizontal shading in Fig. 1) allowed us to examine whether mere active and passive responses can indeed change stimuli valence, even though they do not entail any functional goals. This condition is also a conceptual replication of previous work (e.g. Chen et al., 2016). The contrast between go and approach (middle horizontal shading in Fig. 1) allowed us to examine whether approach is more than a mere go response and thus adds valence on top of what would be expected by the relationship between valence and action. Similarly, the contrast with avoidance (lower horizontal shading in Fig. 1) allowed us to examine whether also avoidance is more than an active response and whether its negative functional goal would decrease stimulus valence (e.g., as avoidance causes a conflict). These latter two conditions have not been employed before. By using the same go responses *across* blocks, it was also possible to examine if avoidance does not only cause stronger decrease in stimulus valence than approach, but also than non-responses (vertical shading in Fig. 1). This comparison is relevant to understand which responses reduce the value of foods the strongest.

As pre-registered (https://aspredicted.org/PQX_QQ2), it was hypothesized that liking of approached stimuli increases stronger than liking of go stimuli (Hypothesis 2a), which increase stronger in liking than avoided (Hypothesis 2b) and non-responded stimuli (Hypothesis 2c) within their respective task block. Across task blocks, we further hypothesized that avoided stimuli decrease more in liking than non-responded stimuli, which in turn decrease more in liking than approached stimuli (Hypothesis 1). Based on the BSI theory, it was also explored whether changes in valence depend on initial liking of the food pictures that is before any responses were executed. To measure picture liking, participants rated the foods displayed in each block, and we additionally measured the corrugator supercilii and zygomaticus major activity in response to them. These facial muscles get activated in response to negative and positive valence, respectively. By doing this before and after each task block, we were able to calculate the change in explicit (ratings) and implicit (muscle activity) stimulus liking.

2. Methods

2.1. Participants

As pre-registered, we recruited 74 non-vegans (16 male) without any current or past eating disorders from the general population and from the University of Salzburg, using flyers and posts on social media platforms. Assuming 10 % dropouts, the sample size should be sufficient to detect small to medium effects of $d = 0.35$ with 80 % power based on pre-registered power analysis with G*Power 3 (paired-samples t test; Faul, Erdfelder, Buchner, & Lang, 2009). One participant did not show up. The remaining participants were aged between 18 and 68 ($M = 25.55$, $SD = 9.68$), and had a body mass index (BMI) between 17.57 and 33.46 ($M = 21.74$, $SD = 2.94$).

2.2. Materials

Throughout the AAT-GNG, we used sixty images of vegetarian foods (e.g. strawberries, chocolate or bread) from the food-pics_extended database (Blechert, Lender, Polk, Busch, & Ohla, 2019). Example pictures and indexes of the pictures can be found in Appendix C. Additionally, six sine beeps of 300 ms were created using Audacity(R) recording and editing software. For the three blocks in the AAT-GNG, the beeps were grouped in sets of two, each with one beep having a distinguishable higher frequency than the other (set 1: 300 Hz vs 800 Hz; set 2: 400 Hz vs 1000 Hz; set 3: 600 Hz vs 1200 Hz).

2.3. Procedure

As outlined in the following, participants first rated each picture, then completed questionnaires and subsequently conducted the three blocks of the AAT-GNG with each block being enclosed by a pre- and post-evaluation phase. Ethical approval of all procedures has been granted by the ethics committee of the University of Salzburg (27/2018).

2.3.1. Preparation: Pre-rating and picture selection

After participants signed the informed consent, they rated how much they liked each food picture on a 100-point slider scale (0 = Not at all; 100 = Very much). These ratings were used to match the initial liking of the pictures across the task blocks. Using an in-house written R-script, the pictures were first rank ordered from the lowest to highest rating and then divided in ten groups. Each group contained six similarly liked pictures. One picture was then randomly sampled from each group and placed into one of the experimental conditions (go in Approach Block, go in Avoid Block, go in GNG Block, non-responses, approach, avoid). To test whether this procedure resulted in similar average liking as well as similar liking distributions for each combination of experimental conditions, we used t-tests and Kolmogorov-Smirnov D. If the t- or D-value was below 0.5, the sampling was repeated.

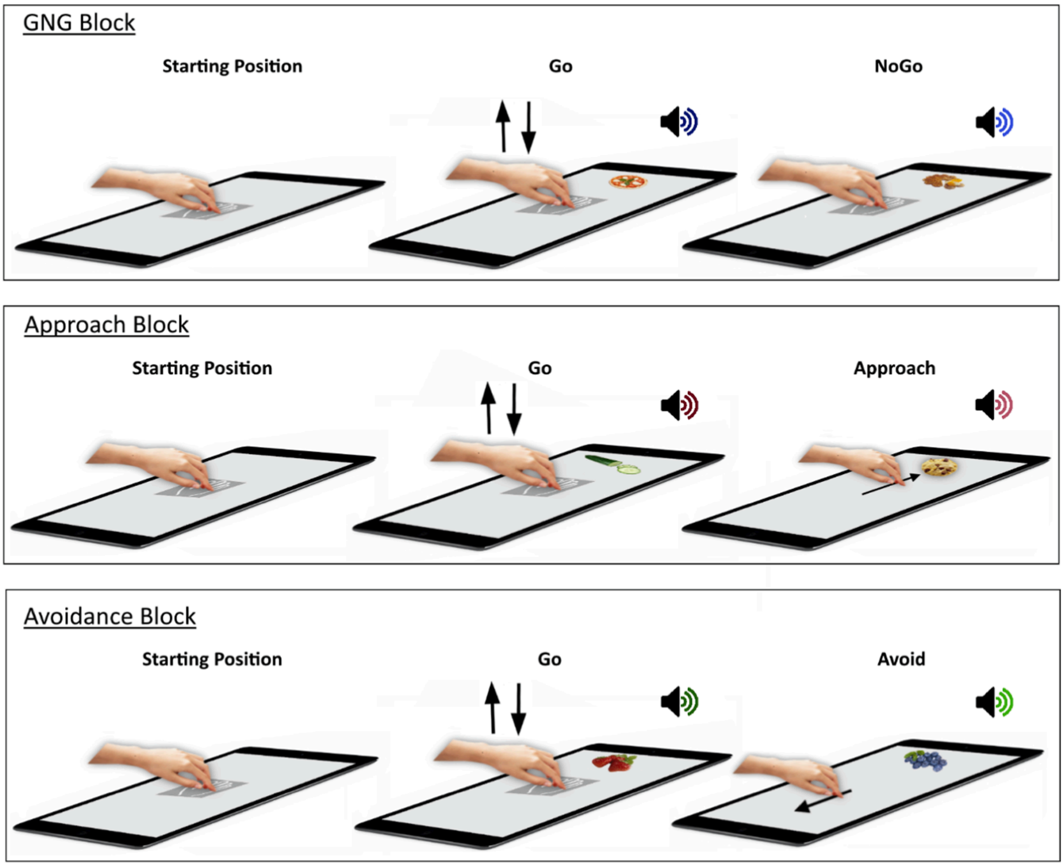

Fig. 2. Illustration of the three task blocks.

2.3.2. Questionnaires

While the script distributed the pictures to the experimental conditions, participants indicated their age, gender, education, height, and weight, and completed the following questionnaires which were used for non-significant exploratory analyses: the German version of the Barrat Impulsiveness Scale (Meule, Vögele, & Kübler, 2011), the Food Craving Questionnaire (Meule, Hermann, & Kübler, 2014) and the external eating subscale of the Dutch Eating Behavior Questionnaire (Nagl, Hilbert, de Zwaan, Braehler, & Kersting, 2016).

2.3.3. AAT-GNG training

After participants completed the questionnaires, they started with the AAT-GNG task. The task, programmed in unity, was administered using a 23-inch iiyama ProLite T2336MSC-B2 touchscreen monitor with a resolution of 1920 × 1080 pixels, placed in portrait-format with a 10 % tilt towards the participant. It contained three separate and fully counterbalanced training blocks (Approach Block, Avoidance Block and GNG Block). Each block contained 100 trials, in which the 20 preselected pictures were randomly displayed for five times.

At the beginning of each trial participants placed their hand on a symbol centrally on the screen, and after a random delay between 300 ms and 700 ms, a stimulus was displayed on the distal side of the touchscreen, followed 100 ms later by one of two possible beeps. The beeps were played through speakers and cued the participants' responses based on how they were instructed and trained in 12 practice trials featuring butterfly pictures before the training block. Participants were instructed to respond as fast as possible. The instructed beep-response associations were counterbalanced with different sets of beeps per block, and different responses for the high or low beep in the set between participants.

In the *GNG* Block (upper row of Fig. 2), one beep indicated that participants should not respond while the other beep indicated that participants should shortly lift their hand and place it back at the same position on the screen, the so-called *go* movement (middle column of Fig. 2). In both cases the picture remained on the screen for 1000 ms. In the *Approach* Block (middle row of Fig. 2), one beep indicated that participants should *approach* the picture by sliding their hand towards it (on average it took participants 887 ms to reach the stimulus). The image then 'snapped' to the hand and could be moved back towards the center of the screen, simulating a naturalistic 'grabbing' action. The other beep cued the same *go* movement as in the GNG Block. The picture again remained on the screen for 1000 ms for the *go* movement, whereas it disappeared after it was pulled to the center on approach trials. In the *Avoidance* Block (lower row of Fig. 2), one beep indicated that participants should *avoid* the picture by sliding their hand away from the stimulus to the 'avoidance zone' at the proximal side of the touchscreen, after which it disappeared (on average 981 ms), while the other beep cued the *go* movement. For the *go* movement, the picture again remained on the screen for 1000 ms. Thus, across blocks, non-responses, approach and avoidance were contrasted against the same *go* movement.

2.3.4. Pre- and Post-evaluations: Ratings and electromyography

Before and after each AAT-GNG Block, the pictures of the respective Block were evaluated on a 1920 × 1080 Pixel computer screen, using E-Prime 2.0 Professional (Psychology Software Tools, Inc., Sharpsburg, PA, USA). As each AAT-GNG Block featured 20 pictures, there were 20 rating trials. Each rating trial started with an 800 ms fixation cross, which was followed by one of the pictures and, after a 2000 ms passive stimulus viewing, a slider beneath the image, prompted participants to rate how much they like the displayed stimulus from 0 (=Not at all) to 100 (=Very much). The sequence of the pictures remained fixed for the pre- and post-evaluation within each participant but differed between participants.

During the passive stimulus viewing interval, facial muscle activity

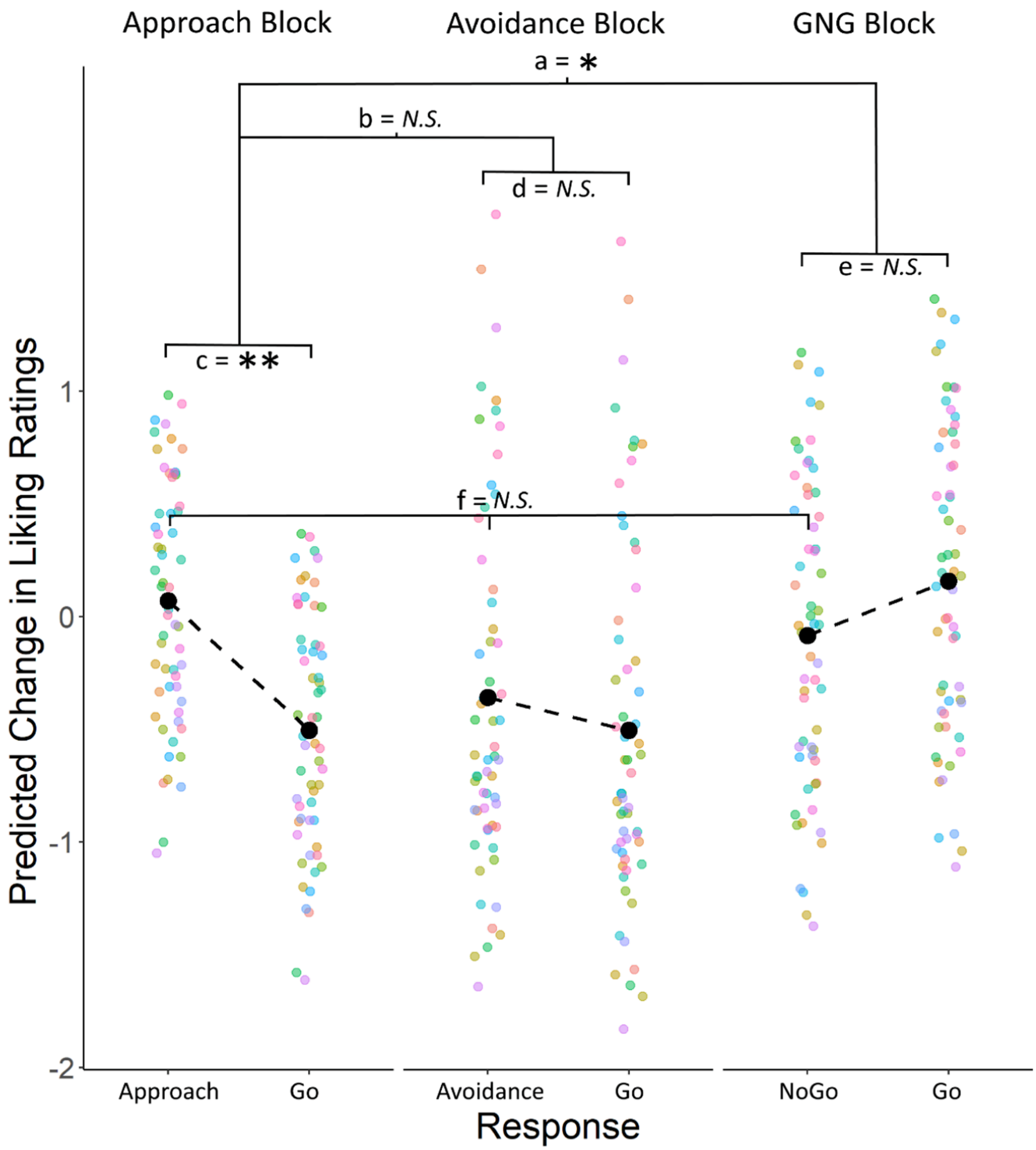

Fig. 3. Change in Liking Ratings Note. N.S. = not significant, * = significant based on 90 % credibility interval, ** = significant based on 95 % credibility interval. Colored points indicate individual participants.

was recorded by four 2 mm inner diameter Ag/AgCI electrodes. Two electrodes were placed on the corrugator supercilia muscle region above the left eye and two on the musculus zygomaticus major region on the left cheek according to Fridlund and Cacioppo (1986). Data was pre-processed in ANSLAB (Blechert, Peyk, Liedlgruber, & Wilhelm, 2016). We applied 28 Hz high-pass and 50 Hz notch filters to the signal as well as rectification and smoothing (50 ms moving average). Obvious artifacts (e.g., loose electrode) were manually rejected through visual inspection. Then, the mean amplitude of nine 500 ms time segments spanning from 500 ms before to 4000 ms after stimulus onset was exported and the activity in the pre-stimulus segment was subtracted from the post-stimulus segments as pre-registered. The segments spanning the passive picture viewing (0–2000 ms) were averaged and used in the following analyses.

2.4. Data processing and statistical analyses

Data was shared together with analyses scripts on https://osf.io/x8q2k/. It was pre-processed as preregistered: First, pictures with more than one incorrect response during the AAT-GNG were excluded. Next, difference scores of the remaining pictures were created by subtracting the pre-rating and pre-muscle activity from the post-rating and post-muscle activity, respectively. Thus, positive difference scores represent an increase in liking ratings or muscle activity whereas negative ones represent a decrease. Second, means of the difference scores for the remaining pictures in each experimental condition were created and used for ANOVAs and t-tests. These pre-registered analyses, together with pre-registered multilevel models and exploratory analyses using different cut-offs for participant exclusion analyses can be found in Appendix A. The exploratory analyses were performed as we deviated from our preregistration in which we specified to exclude participants with more than 75 % error trials in the AAT-GNG task, which – as we

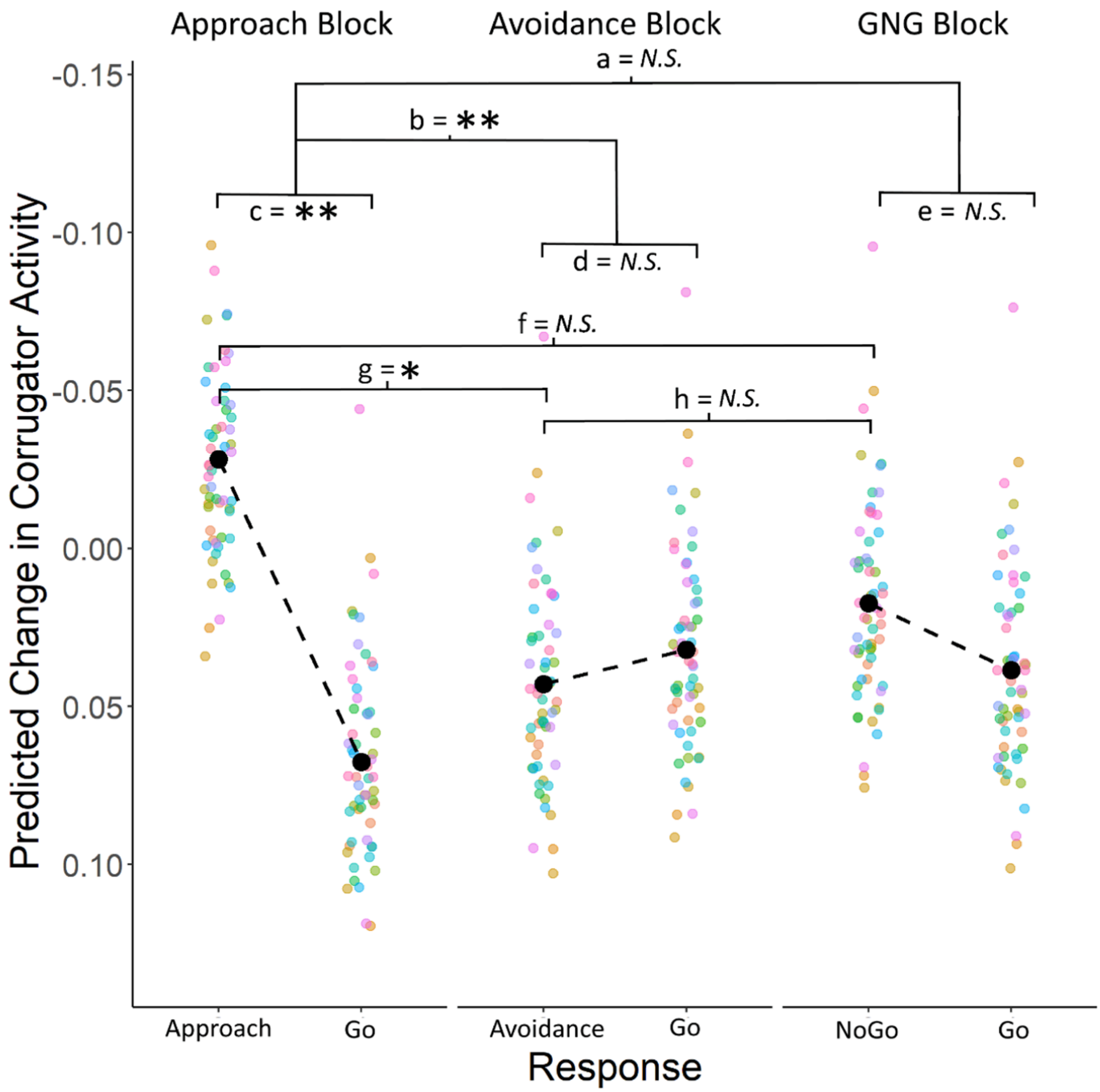

Fig. 4. Change in Corrugator activity Note. The values on the y axis are flipped to align with liking ratings (corrugator activity represents a decrease in liking). N.S. = not significant, * = significant based on 90 % credibility interval, ** = significant based on 95 % credibility interval. Colored points indicate individual participants.

reasoned later - is never reached with 50 % chance level for (in)correct responses. In the following analyses, we thus decided to follow established practice from previous studies and required accuracy of at least 90 % (i.e., < 10 % error trials) for inclusion (Chen et al., 2019; Chen et al., 2016). This resulted into the exclusion of 13 participants from the main analysis. Patterns of results remained the same when instead using accuracy thresholds of 85 %, 87.5 % or 92.5 %, but not when excluding no participant (see Appendix A).

Due to violated assumptions (non-normal distributed residuals and heterogeneous variances between conditions) and for the sake of interpreting null results, we estimated Bayesian multilevel models (BMLM) via the brms package using Stan (Burkner, 2017). Three models either predicting the difference score for liking ratings, corrugator supercilia activity or zygomaticus major activity on a stimulus level were fitted with weakly or non-informative default priors of brms, as they have negligible influence on the results and with a student-distribution as this distribution can account for high kurtosis and yielded the best fit when comparing it to other distributions such as the Gaussian, gen_extreme_value or skew_normal in an unconditional means model. The AAT-GNG blocks (Block: d_0 = Approach Block, d_1 = Avoidance Block, d_2 = GNG Block) and the two responses per block (d_0 = contrasting response, d_1 = go movement) were dummy coded. Random intercepts and slopes were modelled depending on which random structure yielded best model fit.[1] To derive at the best fitting distribution and random effect structure, models were compared using leave-one-out cross validation. Parallel to an alpha level of 5 %, which is usually used in frequentist's statistic, regression coefficients are deemed significant if their 95 % Bayesian credibility interval (CIs) does not include zero. This means there is a 95 % probability that the respective parameter affects the dependent variable, given the evidence provided by the data, priors, and model assumptions. All final models converged with no divergent transitions, Rhat < 1 and ESS greater than 400. Posterior distributions of the fixed effects can be found in Appendix B.

[1] As a maximal random effect structure can causes unstable posterior distributions, it is advised to choose the best fitting model with the lowest number of random effects.

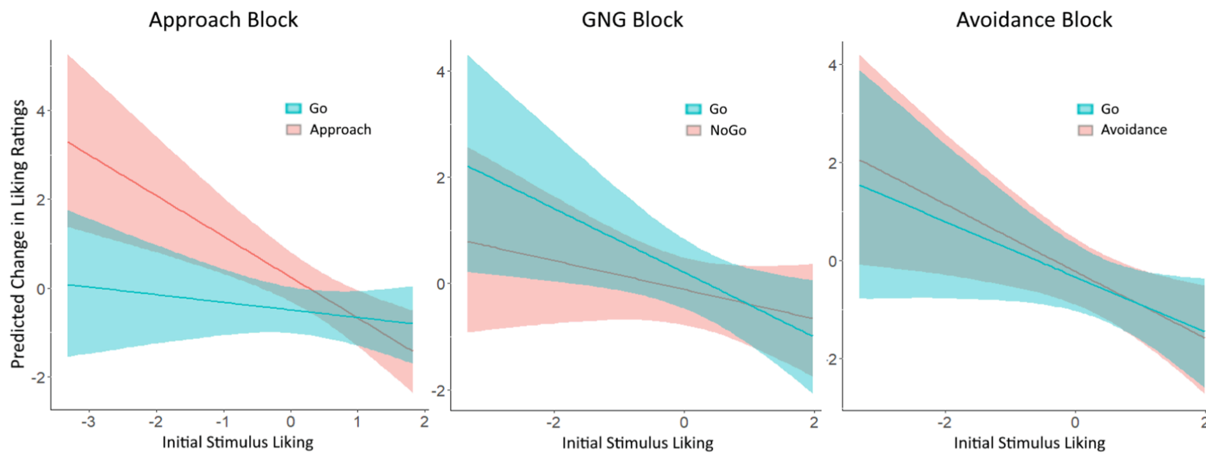

Fig. 5. Change in Liking Ratings depended on the initial picture liking before the AAT-GNG: 'valuation' of less liked foods after approach.

3. Results

3.1. Liking ratings

We tested whether the change in liking ratings differed between approached, avoided and non-responses pictures relative to the go pictures using the following formula:

$$\begin{aligned} &ChangeLikingRatings \sim Block \times ResponseType + (Block|Subject) \\ &Sigma \sim Block \times ResponseType + (Block|Subject) + (Block|Stimulus) \end{aligned} \quad (1)$$

A trend level interaction between the dummy variables GNG Block and go movement (Fig. 3a: b = 0.82, 95 %-CI = [-0.04, 1.69], 90 %-CI = [0.11, 1.54]), indicated that the relative change in liking across the Approach Block (go vs approach) differed from the relative change in linking in the GNG Block (go vs non-responses). The relative liking change for the two responses in the Approach (go vs approach) and Avoidance Block (go vs avoidance) did not differ from each other (Fig. 3b: b = 0.40, 95 %-CI = [-0.47, 1.25]). Pre-registered follow-up tests confirmed that go movements caused a stronger decrease in liking than approach movements (Fig. 3c: b = -0.60, 95 %-CI = [-1.22, 0.00]), whereas go movements did not cause a stronger decrease in liking than avoid responses (Fig. 3d: b = -0.16, 95 %-CI = [-0.78, 0.46]) or non-responses (Fig. 3e: b = 0.17, 95 %-CI = [-0.48, 0.82]) in the respective Block. Across the Blocks, the change in liking after approaching, avoiding, and not responding to pictures did not significantly differ (Fig. 3f: contrast between approach and avoidance: b = -0.56, 95 %-CI = [-1.40, 0.29]; contrast between approach and not responding: b = -0.23, 95 %-CI = [-1.05, 0.54]; contrast between avoidance and not responding: b = -0.36, 95 %-CI = [-1.23, 0.48]). We further explored whether go responses have diverging effects on stimulus valence depending on the Block they were in. Go responses in the GNG Block caused a stronger increase in liking than go responses in the Approach Block (b = 0.74, 95 %-CI = [0.08, 1.42]) and in the Avoid Block at trend-level (b = 0.64, 95 %-CI = [-0.02, 1.30], 90 %-CI = [0.09, 1.20]). Go responses in the Approach and Avoidance Block do not differ from each other (b = 0.08, 95 %-CI = [-0.54, 0.69]).

3.2. Facial muscle activity

To confirm that liked pictures elicit weaker corrugator activity than disliked pictures and that the opposite relationship holds true for zygomaticus activity, the zygomaticus and corrugator activity before the task were related to the liking ratings at the same timepoint, using equation (2). Liking ratings were standardized within participants. As expected, corrugator activity decreased significantly with higher liking ratings (b = -0.02, 95 %-CI = [-0.04, −0.01]). Yet, other than expected, the zygomaticus activity did not increase with stimulus liking (b = 0.00, 95 %-CI = [0.00, 0.01]). Analyses of non-significant effect of the AAT-GNG on the zygomaticus were moved to the appendix A.

$$\begin{aligned} &PreCorrugator/ZygomaticusActivity \sim PreLiking + (PreLiking|Subject) \\ &Sigma \sim PreLiking + (PreLiking|Subject) \end{aligned} \quad (2)$$

With corrugator activity reflecting stimulus disliking, the changes in corrugator activity after the AAT-GNG approximately mirrored the changes in liking ratings. Using equation (3), we found that the relative change in corrugator activity between the two responses in the Approach Block differed from the relative change in corrugator activity between the two responses in the Avoidance Block (Fig. 4b: b = -0.10, 95 %-CI = [-0.20, 0.00]). The relative change in corrugator activity for the two responses in the Approach and in the GNG Block did not differ from each other (Fig. 4a: b = -0.07, 95 %-CI = [-0.17, 0.04]). Pre-registered follow up tests indicate that – in correspondence with the ratings - go movements caused a stronger increase in corrugator activity (i.e., stronger disliking) than the approach movements (Fig. 4c: b = 0.09, 95 %-CI = [0.02, 0.16],), whereas go movements did not cause a stronger change in corrugator activity than avoid responses (Fig. 4d: b = 0.01, 95 %-CI = [-0.09, 0.07]) or non-responses (Fig. 4e: b = -0.02, 95 %-CI = [-0.09, 0.06]) in the respective block. Across the blocks, the avoid response caused a stronger increase in corrugator activity than the approach response (Fig. 4g: b = 0.07, 95 %-CI = [-0.01, 0.15], 90 %-CI = [0.01, 0.14]), whereas corrugator activity did not differ between the approach and the non-response (Fig. 4f: b = 0.05, 95 %-CI = [-0.03, 0.13]) or between avoid and non-responses (Fig. 4h: b = -0.02, 95 %-CI = [-0.10, 0.06]). Exploratory analyses revealed that the effect of the go responses did not depend on the blocks they were in (contrast between approach and avoidance: b = -0.02, 95 %-CI = [-0.10, 0.05]; contrast between approach and not responding: b = -0.02, 95 %-CI = [-0.09, 0.05]; contrast between avoidance and not responding: b = -0.00, 95 %-CI = [-0.08, 0.08])

$$\begin{aligned} &ChangeCorrugatorActivity \sim Block \times ResponseType + (1|Subject) \\ &Sigma \sim Block \times ResponseType + (Block|Subject) \end{aligned} \quad (3)$$

3.3. Exploratory: Effect of initial stimulus liking

We additionally explored whether effects depended on initial liking of the foods, given that the BSI theory assumes stronger changes for highly liked foods, by adding the interactions with the initial liking ratings according to this formula:

$$ChangeLikingRatings \sim Block \times ResponseType \times PreLiking + (Block + PreLiking|Subject)$$
$$Sigma \sim Block \times ResponseType \times PreLiking + (Block + PreLiking|Subject) \quad (4)$$

Initial liking ratings were standardized within participants. A negative main effect for initial liking ratings indicated that lower rated foods increase stronger in liking ratings than higher rated foods, b = -1.39, 95 %-CI = [-2.06, −0.75]. The previously shown trend-level interaction between the two responses in the Approach Block and in the GNG Block attained significance (b = 0.98, 95 %-CI = [0.13, 1.85]), again indicating that the difference between approach and go differed from the difference between non-responses and go in the GNG Block. This effect was further qualified by a significant three-way interaction with initial liking ratings (b = -1.22, 95 %-CI = [-2.17, −0.30]). Follow up analyses in the Approach Block indicated that the effect of approach depended on initial liking ratings, but the effect of go did not. Specifically, the significant interaction between response type and initial liking ratings (b = 0.75, 95 %-CI = [0.08, 1.42]) together with the negative slope for approached foods (b = -0.92, 95 %-CI = [-1.44, −0.42]) suggest that approach led to increased valuation of initially lower rated foods but go did not. In the GNG Block, changes in liking for non-responded stimuli did not depend on initial liking rating (b = -0.28, 95 %-CI = [-0.75, 0.18]) and while the slope for initial liking ratings was also not significantly steeper for go pictures (b = -0.33, 95 %-CI = [-1.03, 0.36]), visual inspection (Fig. 5) indicated that the previously shown 3-way interaction with the Approach Block emerged because negatively rated go pictures increased more strongly in liking compared to non-responded stimuli in the GNG Block, but they increased *less* strongly in liking than approached stimuli in the Approach Block.

For the sake of completeness, we also examined the effect of initial liking in the Avoidance Block which revealed that avoided foods increase stronger in liking when their initial ratings were low (b = -0.68, 95 %-CI = [-1.24, −0.14]) but so did go pictures as indicated by the insignificant interaction between response type and initial liking ratings (b = 0.12, 95 %-CI = [-0.67, 0.92]).

For the corrugator and zygomaticus, there were no interactions with initial stimulus ratings (all 95 % and 90 %-CI contained zero).

4. Discussion

Based on the ongoing discussion about the effectiveness of stimulus response trainings in the domain of eating, we investigated whether the distinction between active and passive responses (as in the GNG) is the critical component to change valence of food stimuli, or whether the functional goals of an action influence stimulus valence as well (as in the AAT). To do so, we contrasted mere active responses (go) with either non-responses, approach, or avoidance. As expected, approached stimuli increased more in liking than go stimuli. This effect was present in explicit liking ratings as well as facial EMG (corrugator activity), and thus is probably due to both explicit and implicit processes. However, results showed that our touchscreen adapted GNG failed to show the expected stimulus devaluation after non-responses. Moreover, avoidance did not cause stimulus devaluation relative to go.

4.1. Mere action vs non-action

The reasons why we were not able to replicate effects of the GNG (e.g. Chen et al., 2016) may be due to some changes from the protocol used in previous work. While the number of stimulus–response pairings, the proportion of go and non-response trials, the timing of the auditory cues as well as the prior sorting procedure matched previous GNGs, the rating task was slightly different. Here we required participants to withhold their rating responses for 2 s upon picture presentation (to measure EMG undisturbed by ratings), whereas participants in previous GNG studies could rate the pictures directly after onset. Possibly active and passive responses primarily change *rapid* evaluative processes, and effects weaken for slower and more deliberate choices. In line with this, effects of GNG on value-based decision making are stronger when people choose more quickly (Chen et al., 2019; Chen, Holland, Quandt, Dijksterhuis, & Veling, 2021). Thus, as previous studies show potentiated GNG effects for fast evaluations, the delayed rating in the current task may be the reason why previous effects were not replicated.

What speaks against this reasoning is that the corrugator reflected no devaluation of non-responded stimuli as well, despite measuring across the full picture duration. However, it may also be that the GNG does generally not affect facial responses. To our knowledge, no other study investigated whether the GNG affects subsequent facial EMG during stimulus viewing, but current findings line up with non-significant changes in the implicit associations task (Jones et al., 2016), a reaction time task which measures the strength of implicit associations between one stimulus class (e.g., foods) with another (e.g., positive/negative). Together with current null results in facial EMG, this may suggest that the GNG does not change implicit evaluations and previous effects on explicit food ratings and choices are not mediated by them.

Another explanation may have to do with the instructions. For example, according to the evaluative coding account (Eder & Rothermund, 2008) instructions bind affective ‘feature codes’ to the movements and thus depending on how instructions are framed, responses may be either transferring positive or negative valence to a stimulus. Specifically, in our case, the instructions[2] for go and non-responses may have been framed more neutral than in previous studies. Another possible explanation may be that changes in stimulus evaluation are partly mediated by remembered stimulus–response pairings (Chen et al., 2018) and the more complex design with three instead of one task block in the current study may have made it more difficult to remember such pairings. Thus, while it is unclear why exactly previous effects were not replicated, our study either suggests that mechanisms other than mere action vs inaction (e.g., instructions or memory effects) are the critical component to change stimulus valence in the GNG task or that effects induced by the action vs non-action are not robust enough to transfer to more implicit outcome measures or different task set-ups such as touchscreens.

4.2. Functional movement goal or interpretation

Contrary to null effects in the GNG block, approached stimuli were liked more than go stimuli. The fact that both responses are active allows for the conclusion that approach is something more than a mere active response. First, approach is distinct from go because it leads to the attainment of the stimulus (i.e., participants grab it and pull it towards themselves) and second approach differed from go because it required more effort to be executed. Instrumental responses (e.g., determined by a positive action outcome) and action vigor may be important characteristics to affect stimulus valence as both have been positively related to

[2] Instructions: Wenn Sie den einen Ton hören, klicken Sie auf das Handsymbol, indem Sie ihre Hand kurz vom Bildschirm lösen und direkt wieder auf den Bildschirm legen (= click on the hand symbol by briefly lifting your hand from the screen and placing it directly back on it). Wenn Sie den anderen Ton hören, lassen sie ihre Hand ruhig auf dem Bildschirm legen und warten bis das nächste Bild erscheint (= keep your hand still on the screen and wait for the next picture to appear).

predicted outcome value of a stimulus via enhanced dopaminergic signalling (da Silva, Tecuapetla, Paixao, & Costa, 2018; Syed et al., 2016). While we did not manipulate action vigor in the current study, a previous GNG study has indeed shown that mere go responses do not affect stimulus valence unless an adaptive staircase procedure enforced vigorous go responses (Chen et al., 2016). Using the same staircase procedure, other studies also showed a long lasting (up to six month) increase in choices for vigorously responded stimuli and showed that increased choices were accompanied by activity in the ventromedial PFC, a region assumed to reflect increased subjective value (Salomon et al., 2018; Schonberg et al., 2014). However, action vigor cannot be the only mechanism how approach affected stimulus valence in the current study as otherwise we would expect increased liking after avoidance as well. That is because avoidance closely resembled approach except for the opposite direction in relation to the stimulus.

Avoided stimuli were not disliked more than go stimuli. This challenges most AAT theories which assume that both approach *and* avoidance are distinct from other classes of actions because they are associated with specialized motivational systems or because approach is usually executed to attain positive outcomes and avoidance to prevent negative ones. Through these response-valence associations, both movements are assumed to affect stimulus valence and in turn health-related behaviors (Eder & Rothermund, 2008; Neumann et al., 2003; Van Dessel, Eder, et al., 2018). So, while we previously showed that stimulus valence has opposing effects on both approach *and* avoidance speed (Van Alebeek et al., 2023), the present study questions the reverse, namely that approach and avoidance also have opposing effects on stimulus valence. The relationship between avoidance and negative valence may be ambivalent as avoidance is usually executed in response to *negative* stimuli but leads to *positive* end-states such as the attainment of safety (Oleson, Gentry, Chioma, & Cheer, 2012).

Thus, previous changes in implicit and/or explicit liking for foods and sweet beverages after the AAT (Krishna & Eder, 2019; Van Dessel, Hughes, & De Houwer, 2018; Zogmaister, Perugini, & Richetin, 2016) may be explained by increased liking of approached stimuli, and not by decreased liking of avoided stimuli. This should be further replicated and confirmed in future studies by including untrained stimuli during the evaluative phase and testing whether approach but not avoided stimuli show stronger changes in valence than untrained ones. If findings are confirmed, this will have major implications for the interpretation of former AAT studies and for potential clinical applications of the AAT. First, in randomized controlled intervention which use a counter-control condition with 90 % approach and 10 % avoidance trials, the interpretation of the control condition and intervention should be reversed (i.e., intervention is active for stimuli approached in the control condition). In line with this, studies using a control condition with 50 % approach and 50 % avoidance trials may be seen as including no active intervention arm and studies in which the dependent variable targeted the avoided food only may not effectively measure the effect of the intervention. Indeed, when reviewing the few randomized controlled AATs which effectively changed food intake, it turned out that all of them incorporated a counter-control condition (e.g., participants approach healthy foods and avoid unhealthy ones; commented on by Becker, Jostmann, & Holland, 2018) and quantified intake of avoided unhealthy food items relative to the intake of approached healthy foods (Fishbach & Shah, 2006; Kakoschke et al., 2017b; Schumacher, Kemps, & Tiggemann, 2016). For clinical application it may be thus advisable to use the AAT when the aim is to increase the relative proportion of certain foods items (e.g., healthy foods) in someone's diet.

That results were consistent across liking ratings and corrugator activity highlights further what kind of evaluations can be changed by approach. Explicit ratings and corrugator activity often go hand in hand (i.e. as also seen by the negative correlation in the current study), but may also diverge when demand characteristics of experiments influence explicit self-reports only or when people have ambivalent implicit and explicit motives towards a stimulus (e.g., in binge eating: Leehr et al., 2016; Svaldi, Tuschen-Caffier, Peyk, & Blechert, 2010). This is because corrugator activity is assumed to measure implicit evaluations which are not easily regulated by explicit motives. Specifically, in previous studies, its activity corresponded to valence of *subliminal* stimuli and participants were unable to suppress it willingly (Bornemann, Winkielman, & van der Meer, 2012; Dimberg, Thunberg, & Grunedal, 2002). Thus, approach relative to neutral responses may be able to change implicit as well as explicit evaluations of foods. The former is probably most influential early during the evaluative process, as also supported by exploratory analyses in which responses affected corrugator activity more consistently during the first half than during the second half of the two second window (see Appendix A). The latter probably takes effects later during the evaluative process and thus could be measured after a delay of 2 s in the current study.

This contrasts with previous findings of the GNG task. As described above, choices for go relative to non-responded foods were potentiated for speeded evaluations. Together with the findings that either speeded motor responses or responses in a choice task led to the disappearance of GNG-induced stimulus devaluation or decreased them (Chen et al., 2021; Liu, Veling, Blechert, Quandt, & Holland, in preparation), we speculate that approach can induce more robust changes in liking than non-responses as it targets implicit and explicit evaluations. This may also explain why one of the direct comparison studies showed more healthy food choices after the AAT than GNG (Kakoschke et al., 2017a) while there were no differences on implicit evaluations and the other comparison study showed changed liking ratings after the AAT (but not after the GNG) while there were no differences in food choices (Veling et al., 2021). Crucially, the measures which were affected by the AAT only were taken *after* the measures affected by both trainings and which required speeded food responses. This possibly points to more durable training effects for approached than non-responded stimuli.

That effects in the AAT are mostly due to increased liking of approached stimuli is further supported by the exploratory analyses which revealed that approach relative to go affected initially less liked foods more so than initially more liked foods. Due to ceiling effects, initially lower rated stimuli have more room to increase in liking after the task than stimuli which were already rated high from the beginning. Because in previous GNG studies specifically non-responses caused devaluation of stimuli, such simple ceiling or floor effects may explain why approach vs go in the current study mainly affects low rated stimuli whereas active vs passive responses in some of the previous GNG studies mainly affect initially high rated stimuli (Chen et al., 2016; Veling et al., 2021). Alternatively, the exploratory results may be explained by the BSI theory: arguing from this theory, the disliked foods increased stronger in valence than the liked ones because the conflict when participants approach negative stimuli is resolved through stimulus upvaluation.

4.3. Limitations

The study entailed some limitations. While at face validity and based on previous studies, the zygomaticus major – also called smiling muscle – should be able to pick up changes in subjective stimulus valence. Yet, it was probably not suitable to investigate fine grained subjective liking of foods: zygomaticus activity was not related to stimulus liking in the current study and previous studies showed its activation in response to disgust-related stimuli and that it responds less reliably to valence of picture, word, or sounds than the corrugator (de Jong, Peters, & Vanderhallen, 2002; Larsen, Norris, & Cacioppo, 2003). In turn, corrugator activity was shown to depend on the context with moderately pleasant pictures eliciting less corrugator activity (more liking) when displayed together with mildly pleasant as opposed to extremely pleasant pictures (Larsen & Norris, 2009). These context-dependent effects were not present for unpleasant pictures and thus corrugator activity may have been especially suitable to measure relative differences in liking for generally positive pictures such as foods, but the zygomaticus was not.

Further, we deviated from our pre-registration by following stricter, but established practises on participant exclusion and by using Bayesian instead of Frequentist approaches. This deviation allowed us to model heterogeneous variance and kurtosis in the data but should have been anticipated beforehand to reduce the number of analyses.

Another limitation is that it is difficult to separate the effect of go from the other responses on stimulus valence. Go responses were used across blocks because even if we had used evaluations of untrained stimuli and could thus distinguish, for example, whether approach stimuli specifically increase valence and not just in comparison to avoided ones, it would be still unclear whether this increase was due to the contrast with avoidance or because approach in itself is associated with positive stimulus valence. Such contrasts effects are quite common with mediocre stimuli appearing more positive when displayed together with negative ones (Tousignant & Bodner, 2014). To systematically compare approach, avoidance, and non-responses, we held the contrast consistent by using the same relatively neutral go response across blocks. Following this logic, current results indicate that responses which are usually assumed to be the active ingredient in stimulus–response trainings (i.e., non-responses and avoidance) were similarly *in*effective. Yet, we did not consider that the effect of the go response may also depend on the contrasted response. For example, go may be perceived negative when executed together with approach, whereas it may be perceived positive when executed together with avoidance or non-responses. Indeed, we showed that go stimuli in the Approach Block are rated more negative than in the GNG Block. This effect was however not present in the corrugator and clear conclusions are unwarranted; after all, differences in go responses may be caused by increased liking of all stimuli in the GNG block due to movement-unspecific effects and not by go responses having different effects on stimulus valence depending on their contrasted response contrast.

4.4. Conclusion

Null results in the GNG point researchers to caution when changing the timing of evaluations or adapting it to different contexts e.g., the touchscreen. This is especially relevant as stimulus–response trainings, including the GNG, are increasingly implemented on smartphones to train people in their everyday environment and make the training more accessible for every-one (Aulbach, Knittle, van Beurden, Haukkala, & Lawrence, 2021). That avoidance did not differ from go, but approach did, highlights that approach may be more than a mere active response, whereas avoidance is not – at least in the context of appetitive foods. This has theoretical implications for future stimulus–response trainings. It appears possible that aims to reduce consumption, e.g., of unhealthy foods, are more effectively treated with non-responses than avoidance whereas aims to increase consumption, e.g., for healthy foods, are more effectively treated with approach than go movements. To combine both mechanism, researchers may investigate if the GNG profits from replacing the relatively neutral go movements with approach or, likewise, if the AAT profits from replacing the avoidance movements with non-responses.

CRediT authorship contribution statement

Hannah van Alebeek: Conceptualization, Writing – original draft, Writing – review & editing, Software, Project administration, Investigation, Formal analysis, Data curation, Visualization. **Harm Veling:** Conceptualization, Writing – review & editing. **Jens Blechert:** Conceptualization, Investigation, Resources, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data was shared together with analyses scripts on https://osf.io/x8q2k/

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Appendix

Appendix A

Effect of the AAT-GNG on zygomaticus activity

For the zygomaticus activity, none of the effects reached significance. Using equation (5), the difference between the go and approach movement in the Approach Block did neither differ from the difference between the go and avoid response in the Avoidance Block (b = 0.01, 95 %-CI = [-0.04, 0.05]) nor from difference between the go and non-response in the GNG Block (b = 0.01, 95 %-CI = [-0.03, 0.05]). We still followed-up as pre-registered: go movements did not differ from approach (b = -0.01, 95 %-CI = [-0.04, 0.02]), avoidance (b = 0.00, 95 %-CI = [-0.04, 0.04]), or non-responses (b = 0.00, 95 %-CI = [-0.03, 0.02]) in the respective block and approach, avoidance and non-responses did not differ from each other as well (contrast between approach and avoid: b = 0.00, 95 %-CI = [-0.04, 0.04]; contrast between approach and not responding: b = 0.01, 95 %-CI = [-0.02, 0.05]; and contrast between avoid and not responding: b = 0.02, 95 %-CI = [-0.03, 0.06]).

$$\begin{aligned} &ChangeZygomaticusActivity \sim Block \times ResponseType + (1|Subject) \\ &Sigma \sim Block \times ResponseType + (Block|Subject) + (1|Stimulus) \end{aligned} \tag{5}$$

Explicit stimuli ratings – Pre-registered results

We tested whether the change in liking ratings differed between approached, avoided and non-responded stimuli relative to the go stimuli by using an 3x2 RM-ANOVA with block type (Approach Block, Avoidance Block and GNG Block) and responses in the block (go vs other response in the block). Change in linking differed indeed as indicated by a significant interaction, $F\,(2, 112) = 4.61$, $p = .012$, $\eta^2_{generalized} = 0.02$, which was followed up by

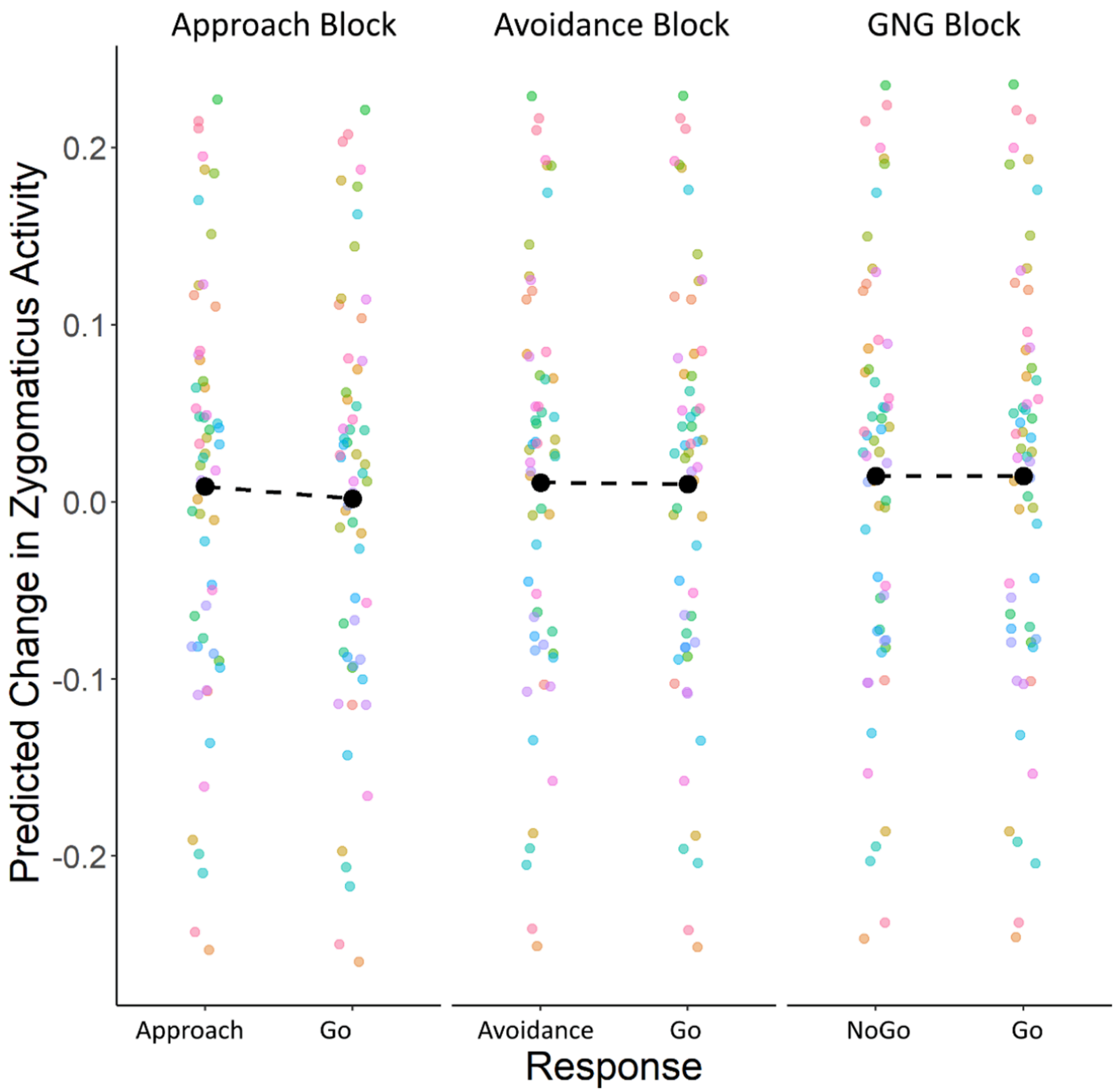


Fig. 6. Changes in zygomaticus activity after the AAT-GNG.

preregistered dependent t-tests. The pairwise comparisons revealed that approached stimuli decrease less in liking than go stimuli from the same block, $t\,(58) = 2.75$, $p = .008$, $d = 0.39$, whereas no differences were found for avoided, $t\,(57) = -1.09$, $p = .279$, $d = -0.159$) and non-responded stimuli, $t\ (57) = -0.739$, $p = .463$, $d = -0.101$, relative to go stimuli from the respective block. Approached, avoided and non-responded stimuli did not significantly differ from each other, $F\,(2, 112) = 1.51$, $p = .226$, $\eta^2_{generalized} = 0.02$, as well as the go stimuli across blocks, $F\,(2, 112) = 1.51$, $p = .108$, $\eta^2_{generalized} = 0.02$.

We additionally used frequentists' multilevel models (MLM) to predict the change in liking ratings with the dummy coded variables Block type, response per Block and their interaction as fixed effects as well as with random intercepts per participant. Due to convergence issues, we did not model random slopes per participant. As preregistered, a predictor is deemed of explanatory value if the model without it performed significantly worse on the likelihood-ratio test. Model fit decreased significantly when dropping the interactions, $\chi2\ (2) = 8.51$, $p = .014$, $\beta_{AvoidanceBlock*go} = 0.08$, $\beta_{GNGBlock*go} = 0.08$, suggesting that the difference between the go movement and the other response in at least one of the blocks is larger than in the Approach Block. Follow-up tests indicated that liking increases significantly stronger for approached compared to go stimuli, $\chi^2\,(1) = 7.58$, $p = .006$, $\beta_{go} = -0.079$, but the change in liking did not significantly differ between go and avoid, $\chi^2\,(1) = 0.98$, $p = .321$, $\beta_{go} = 0.029$, or go and non-responses, $\chi^2\,(1) = 0.73$, $p = .393$, $\beta_{go} = 0.027$. Pre-registered analyses comparing whether change in linking differed between approached, avoided and non-response stimuli, indicated no differences between approach and non-responses or between approach and avoidance $\chi^2\,(2) = 4.29$, $p = .117$, $\beta_{avoid} = -0.06$, $\beta_{non\text{-}response} = -0.04$.

Explicit stimuli ratings – Different cut-offs for participant exclusion

As we incorrectly preregister how we will exclude participant, we decided to exclude participants with an accuracy below 90 % based on established practise in previous studies (Chen et al. 2019, Chen et al., 2016). However, to check whether results depended on the selected cut-off, we explored whether the general pattern of ANOVA, MLM and BMLM results differ when excluding participants with an accuracy below 85 %, 87.5 % or 92.5 % (Fig. 7). It did not, as the interaction between Block type and responses in the block on liking ratings remained significant across the different cut-offs of ANOVAs (85 %-cut-off: $F\,(2, 122) = 4.18$, $p = .018$; 87.5 %-cut-off: $F\,(2, 118) = 4.39$, $p = .014$; 92.5 %-cut-off: $F\,(2, 100) = 4.00$, $p = .021$) and MLMs (85 %-cut-off: $\chi^2\ (2) = 6.53$, $p = .038$; 87.5 %-cut-off: $\chi^2\ (2) = 7.65$, $p = .022$; 92.5 %-cut-off: $\chi^2\ (2) = 7.71$, $p = .020$) or at trend-level for the

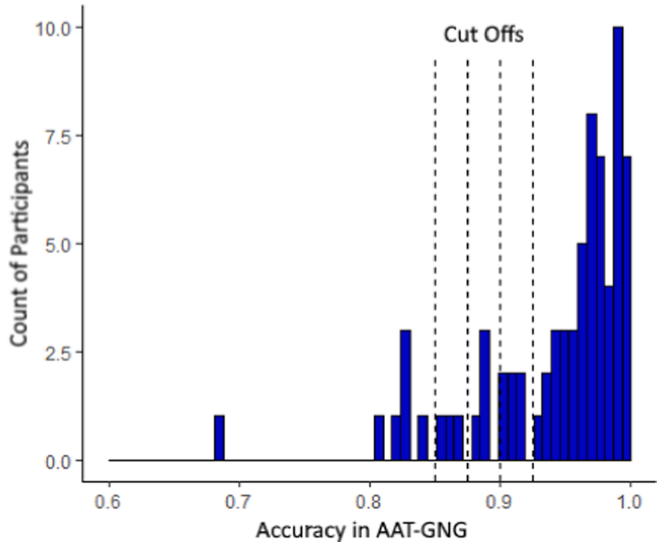


Fig. 7. Different cut-offs for participant exclusion.

interaction between in the dummy variables GNG Block and go movement in the BMLM (85 %-cut-off: b = 0.74, 90 %-CI = [0.03, 1.46]; 87.5 %-cut-off: b = 0.73, 90 %-CI = [0.03, 1.46], 92.5 %-cut-off: b = 0.81, 90 %-CI = [0.07, 1.57]). In addition, follow-up tests showed a similar pattern of results across the different cut-offs: Liking increased stronger for approach than go (all t-tests and MLMs: $p < .025$; all credibility intervals did not include 0), whereas the change in liking did not differ between go and non-responses (all t-tests and MLMs: $p > .347$; all credibility intervals include 0) or go and avoidance (all t-tests and MLMs: $p > .174$; all credibility intervals include 0).

Muscle activity – Pre-registered results

We tested whether the changes in corrugator differed between approached, avoided and non-responded stimuli relative to the go stimuli by using an 3x2 RM-ANOVA with Block type (Approach Block, Avoidance Block and GNG Block) and responses in the block (go vs other response in the Block). The interaction was not significant for change in corrugator activity, F (2, 112) = 1.89, p =.157, $\eta^2_{generalized} = 0.01$. As preregistered, we still followed up with dependent t tests as preregistered: For the corrugator, indexing negative valence, activity increased significantly stronger for approached than go stimuli from the same block (t (58) = -2.27, p =.027, d = -0.28), whereas no differences were found for avoided (t (57) = -0.92, p =.361, d = -0.13) and non-responded stimuli (t (58) = 0.91, p =.367, d = 0.08) relative to go stimuli from the respective block. Activity change for the corrugator did not differ between approached, avoided and non-responded stimuli (F (2, 112) = 1.39, p =.254, $\eta^2_{generalized} = 0.01$). For the zygomaticus, none of the analyses were significant (p >.29).

We additionally used multilevel models (MLM) to predict the change muscle activity with the dummy coded variables Block, response per Block and their interaction as fixed effects as well as with random intercepts per participant. This random effect structure yielded best fitting models based on AIC. As preregistered, a predictor is deemed of explanatory value if the model without it performed significantly worse on the likelihood-ratio test. For the corrugator, model fit decreased at trend level when dropping the interaction, χ^2 (2) = 5.04, p =.081, $\beta_{AvoidanceBlock*go}$ = -0.04, $\beta_{GNGBlock*go}$ = -0.07, suggesting that the difference between the go movement and the other response in the Block differed between the Blocks. Follow-up tests indicated that muscle activity increases significantly stronger for go stimuli compared to approached stimuli, χ^2 (1) = 4.95, p =.026, β_{go} = 0.07, but the change in activity did not significantly differ between go and avoidance, χ^2 (1) = 0.00, p =.954, $\beta_{go} < 0.01$, or go and non-responses, χ^2 (1) = 0.97, p =.325, β_{go} = -0.03, in the respective Block. Pre-registered analyses comparing whether the change in corrugator activity differs between approached, avoided and non-response stimuli, indicated that model fit decreases at trend level when dropping dummy variables Avoid and NoGo, χ^2 (2) = 5.33, p =.069, $\beta_{Avoidance}$ = 0.06, β_{GNG} = 0.06.

For the zygomaticus none of the analyses were significant (p >.395).

Muscle activity – Different cut-offs for participant exclusion

We explored whether the general patterns of ANOVA, MLM and BMLM results differs between various exclusion cut-offs (accuracy < 85 %, 87.5 % or 92.5 %) for the corrugator. The significance levels followed a similar pattern across the cut-offs for the corrugator: The interaction between Block type and responses in the block remained insignificant or at trend level for the ANOVAs (85 %-cut-off: F (2, 122) = 1.67, p =.192; 87.5 %-cut-off: F (2, 120) = 1.44, p =.242; 92.5 %-cut-off: F (2, 100) = 1.66, p =.195) and MLMs (85 %-cut-off: χ^2 (2) = 3.95, p =.139; 87.5 %-cut-off: χ^2 (2) = 3.63, p =.163; 92.5 %-cut-off: χ^2 (2) = 4.75, p =.093). For the BMLM, the interaction between the two responses in the Approach Block and Avoidance Block remained significant (85 %: b = -0.09, 95 %-CI = [-0.19, 0.00]; 87.5 %: b = -0.10, 95 %-CI = [-0.20, 0.00]; 92.5 %: b = -0.12, 95 %-CI = [-0.24, −0.01]). Patterns of the follow-up tests were similar across cut-offs as well: corrugator activity decreased stronger for approach than go (all t-tests and MLMs: $p < .085$; all credibility intervals did not include 0) but did not differ between go and avoid (all t-tests and MLMs: $p > .302$; all credibility intervals include 0) or go and non-responses (all t-tests and MLMs: $p > .301$; all credibility intervals include 0).

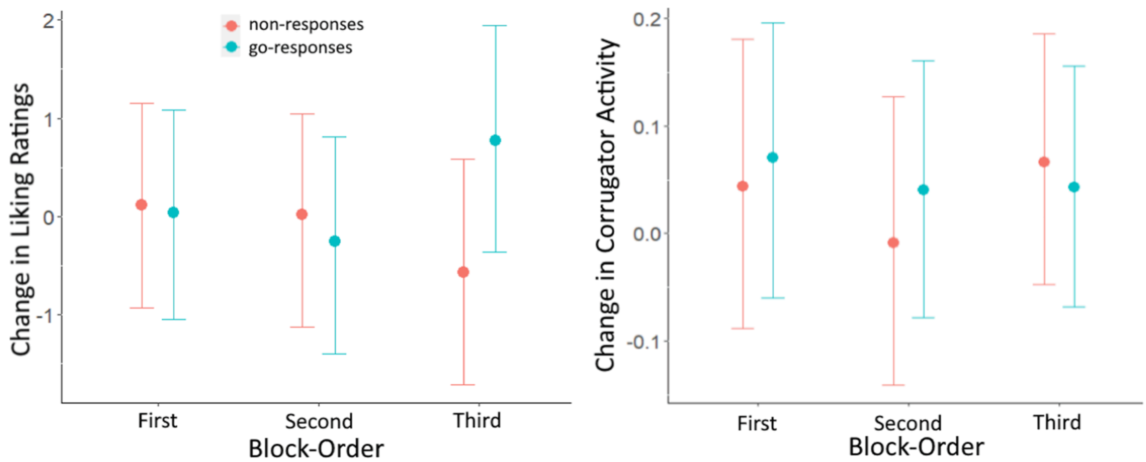


Fig. 8. Liking/corrugator changes after the GNG did not depend on the block-order.

Exploratory analyses of Block-order effects

We explored whether carry-over effects of previous blocks in our within-subject design may have masked changes in liking after go and non-responses. A significant interaction between ResponseType and BlockOrder in equation (6) would indicate that effects of the GNG Block depend on their position within the study (i.e., whether the GNG Block was presented at first, second or third). As seen in Fig. 8, the effects of the GNG were not stronger when it was presented in the first block, compared to when it was presented in the second (liking ratings: b = -0.20, 95 %-CI = [-1.65, 1.29]; corrugator: b = -0.01, 95 %-CI = [-0.22, 0.21]) or third block (liking ratings: b = 1.44, 95 %-CI = [-0.28, 3.18]; corrugator: b = 0.04, 95 %-CI = [-0.16, 0.24]). If any, the GNG has stronger effects when displayed in the last block and thus may depend on previous blocks instead of being masked by them.

$$\begin{aligned}&Difference\ Score\ Ratings/Corrugator\ Activity \sim ResponseType\ (go\ \text{vs}\ non\text{-}responses\ ) * \\ &BlockOrder\ (first,\ second\ or\ third\ Block) + (1|Subject), \\ &Sigma \sim ResponseType * BlockOrder + (1|Subject)\end{aligned} \quad (6)$$

Exploratory analyses of early and late components of the corrugator

To further explore whether approach relative to go affects mainly early or late components of the corrugator, we split the two second measurement window and re-ran analyses for both components separately according to equation (7). Approach decreased corrugator activity stronger (i.e., increased valence) than go in the early component of the two second window (b = 0.09, 95 %-CI = [0.03, 0.15]). This effect was not significant in the late component of the two second window (b = 0.09, 95 %-CI = [-0.01, 0.18]).

$$\begin{aligned}&Difference\ Corrugator\ Activity \sim ResponseType\ (go\ \text{vs}\ approach\ ) + (1|Subject), \\ &Sigma \sim ResponseType + (1|Subject)\end{aligned} \quad (7)$$

Exploratory analyses of the effect of age and weight in the main analyses

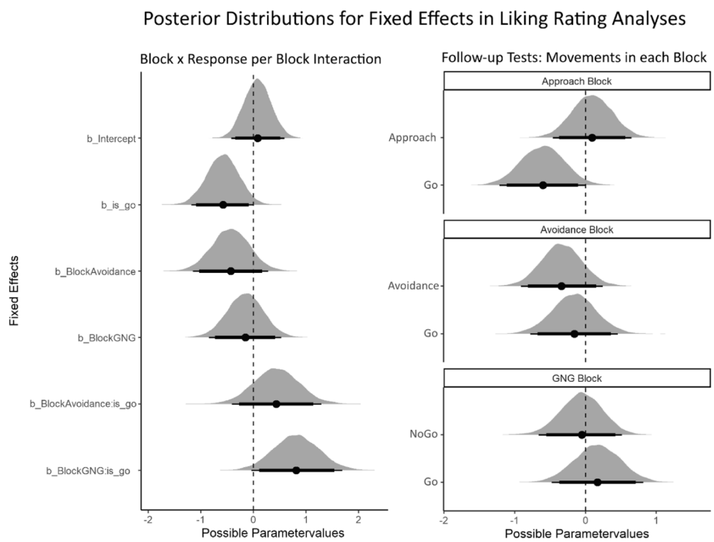
To control for the effect of BMI and age on the change in liking after approach relative to go, we re-ran these follow-up analyses while adding age and BMI as covariates. The effects remained of similar size and significance: approach increased liking ratings stronger than go (b = -0.61, 95 %-CI = [-1.22, 0.00]), and approach decreased corrugator activity stronger than go (b = 0.09, 95 %-CI = [0.02, 0.16]). BMI and age were unrelated to changes in liking ratings (BMI: b = 0.10, 95 %-CI = [-0.05, 0.26]; Age: b = -0.01, 95 %-CI = [-0.09, 0.06]) and to changes in corrugator activity (BMI: b = 0, 95 %-CI = [-0.01, 0.01]; Age: b = 0, 95 %-CI = [-0.01, 0.01]).

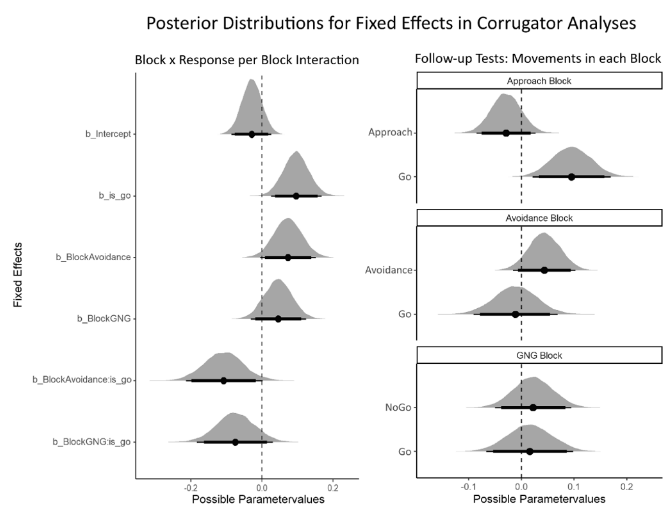
Exploratory analyses of the effect of learning during the AAT-GNG

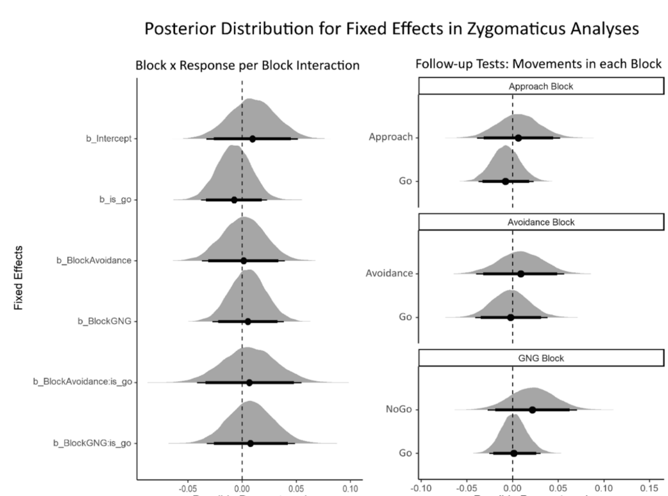
Because changes in evaluations may reduce stimulus–response conflict and thus enable faster responses (e.g. devaluation would make avoidance faster, upvaluation would make approach faster), we explore whether changes in stimulus liking from before to after the AAT-GNG were related to stronger speeding during the AAT-GNG. We extracted the person- and response-specific speeding during the AAT-GNG by predicting the trial-level reaction times with a fixed intercept and a random intercept as well as slope for the time in the task per participant in a multilevel model. The person-specific slopes for the time in the task were then correlated with the change in liking for the stimuli associated with the respective response. Due to non-normality, we used Spearman's rank correlation.

The speeding of the go responses in the GNG, Approach and Avoid Block did not correlate with the change in liking of the respective go stimuli, $r(57) = -0.05$, $p = .706$, $r(58) = 0.12$, $p = .358$, $r(57) = 0.03$, $p = .823$, and speeding of approach and avoidance did also not correlate with the change in liking of approached, $r(58) = -0.06$, $p = .666$, and avoided, $r(58) = -0.11$, $p = .408$, stimuli, respectively. For corrugator activity, we additionally found no significant associations between changes in corrugator activity and speeding of responses for approached stimuli, $r(58) = -0.02$, $p = .869$, avoided stimuli, $r(57) = -0.11$, $p = .422$, and go stimuli in the GNG, $r(57) = 0.06$, $p = .653$, and Approach Block, $r(58) = 0.19$, $p = .154$. There was a trend-level correlation go stimuli in the Avoidance Block, $r(57) = 0.24$, $p = .073$. This suggest stronger decrease in corrugator activity (i.e., increased liking) among participants who strongly increase the speed of go responses over the course of the Avoidance Block.

Appendix B

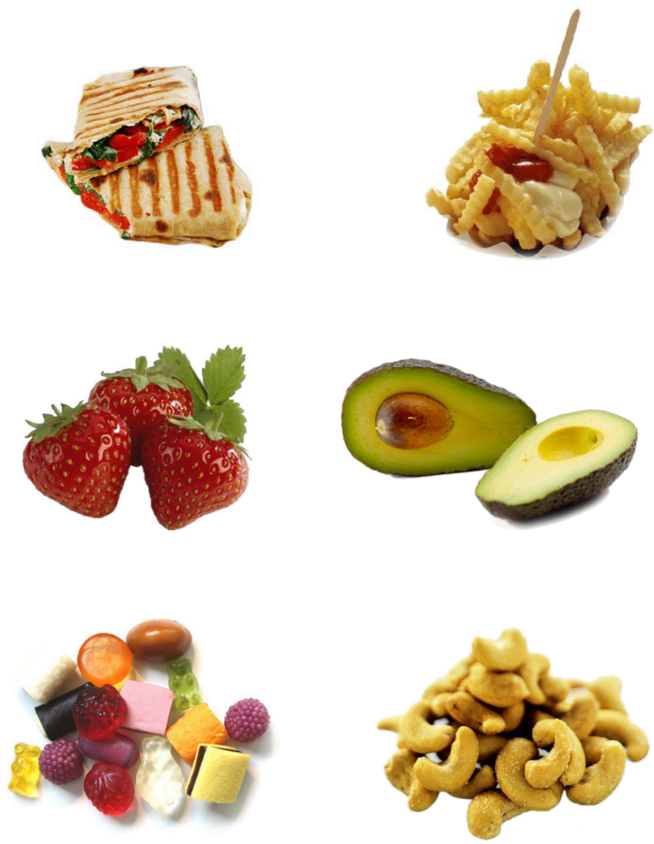

Posterior Distributions for Fixed Effects in Liking Rating Analyses
Block x Response per Block Interaction
Follow-up Tests: Movements in each Block
Fixed Effects
b_Intercept
b_is_go
b_BlockAvoidance
b_BlockGNG
b_BlockAvoidance:is_go
b_BlockGNG:is_go
Approach Block
Approach
Go
Avoidance Block
Avoidance
Go
GNG Block
NoGo
Go
Possible Parametervalues
Possible Parametervalues


Posterior Distributions for Fixed Effects in Corrugator Analyses
Block x Response per Block Interaction
Follow-up Tests: Movements in each Block
Fixed Effects
b_Intercept
b_is_go
b_BlockAvoidance
b_BlockGNG
b_BlockAvoidance:is_go
b_BlockGNG:is_go
Approach Block
Approach
Go
Avoidance Block
Avoidance
Go
GNG Block
NoGo
Go
Possible Parametervalues
Possible Parametervalues


Posterior Distribution for Fixed Effects in Zygomaticus Analyses
Block x Response per Block Interaction
Follow-up Tests: Movements in each Block
Fixed Effects
b_Intercept
b_is_go
b_BlockAvoidance
b_BlockGNG
b_BlockAvoidance:is_go
b_BlockGNG:is_go
Approach Block
Approach
Go
Avoidance Block
Avoidance
Go
GNG Block
NoGo
Go
Possible Parametervalues
Possible Parametervalues

Appendix C

Indexes of stimuli in the food-pics_extended database (Blechert, Lender, Polk, Busch, & Ohla, 2019): 0009, 0016, 0018, 0028, 0051, 0060, 0110, 0113, 0140, 0180, 0197, 0219, 0234, 0317, 0325, 0353, 0394, 0397, 0402, 0426, 0454, 0154, 0567, 0193, 0662, 0664, 0137, 0675, 0682, 0685, 0690, 0705, 0715, 0723, 0347, 0282, 0399, 0761, 0267, 0208, 0194, 0263, 0800, 0189, 0173, 0809, 0169, 0221, 0819, 0517, 0166, 0829, 0192, 0283, 0366, 0187, 0866, 0062, 0869, 0879.



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