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Abstract

Background: Repeatedly pushing high-calorie food stimuli away based on joystick movements has been found to reduce approach biases towards these stimuli. Some studies also found that such avoidance trainings reduced consumption of high-calorie foods.

Objective: To make such interventions suitable for daily use, this preregistered study tested effects of a smartphone-based approach–avoidance intervention on chocolate craving and consumption.

Methods: Within a ten-day period, participants (n = 105, 86% female) either performed five sessions during which they continuously avoided (i.e., swiped away/upwards) chocolate stimuli (experimental group, n = 35), performed five sessions during which they approached and avoided chocolate stimuli equally often (placebo control group, n = 35), or did not perform any training sessions (inactive control group, n = 35). Training effects were measured during laboratory sessions before and after the intervention period and further continuously through daily ecological momentary assessment (EMA).

Results: Self-reported chocolate craving and consumption as well as body fat mass significantly decreased from pre- to post-measurement across all groups. EMA reports evidenced no differences in chocolate craving and consumption between intervention days and rest days as a function of group.

Conclusions: A smartphone-based approach–avoidance training did not affect eating-related and anthropometric measures over and above measurement-based changes in the current study. Future controlled studies need to examine whether other techniques of modifying food approach tendencies show an add-on benefit over conventional, monitoring-based intervention effects.

ClinicalTrial: https://aspredicted.org/pt9df.pdf

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Abstract

Background: Repeatedly pushing high-calorie food stimuli away based on joystick movements has been found to reduce approach biases towards these stimuli. Some studies also found that such avoidance trainings reduced consumption of high-calorie foods. *Objectives:* To make such interventions suitable for daily use, this preregistered study tested effects of a smartphone-based approach–avoidance intervention on chocolate craving and consumption. *Methods:* Within a ten-day period, regular chocolate eaters (n = 105, 86% female) either performed five sessions during which they continuously avoided (i.e., swiped away/upwards) chocolate stimuli (experimental group, n = 35), performed five sessions during which they approached and avoided chocolate stimuli equally often (placebo control group, n = 35), or did not perform any training sessions (inactive control group, n = 35). Training effects were measured during laboratory sessions before and after the intervention period and further continuously through daily ecological momentary assessment (EMA). *Results:* Self-reported chocolate craving and consumption as well as body fat mass significantly decreased from pre- to post-measurement across all groups. EMA reports evidenced no differences in chocolate craving and consumption between intervention days and rest days as a function of group. *Conclusions:* A smartphone-based approach–avoidance training did not affect eating-related and anthropometric measures over and above measurement-based changes in the current study. Future controlled studies need to examine whether other techniques of modifying food approach tendencies show an add-on benefit over conventional, monitoring-based intervention effects.

Keywords

Food; Chocolate; Craving; Approach; Avoidance; Smartphone

Introduction

Training individuals to avoid appetitive stimuli has been found to reduce automatic approach tendencies towards these stimuli. For example, repeatedly pushing pictures of alcoholic beverages “away” on a screen based on joystick movements has been found to reduce approach biases towards alcohol in heavy drinkers [1] and patients with alcohol use disorder [2, 3]. Similar results have been obtained using pictures of high-calorie foods in samples of high trait food cravers [4] or individuals with obesity [5-7]. Although effects on actual consumption behaviors is less consistent [8-10], several studies point towards a decrease in craving for and consumption of appetitive substances through approach–avoidance trainings [11].

While traditional approach–avoidance tasks (AATs) and trainings are usually performed with joystick movements in front of a computer monitor, methods that make these techniques suitable for daily use are needed. One possibility for this is to implement AATs or trainings on smartphones. For example, two recent studies used a smartphone-based training during which participants were required to swipe pictures away or towards themselves to reduce body dissatisfaction [12] or procrastination [13]. While these studies reported promising results (i.e., changes in behavior due to the approach–avoidance intervention), interpretation was limited by the use of inactive (waitlist) control groups and by combining the training with conventional face-to-face treatment elements.

The aim of the current study was, therefore, to evaluate a smartphone-based approach–avoidance training for reducing food craving and consumption in a randomized, fully controlled trial (i.e., by comparing active training effects to placebo and no training groups). As chocolate is the most frequently craved food in Western societies [14, 15], we restricted our study to chocolate-containing foods, similar to previous studies on approach–avoidance modification [16-18]. Specifically, participants were randomly assigned to one of three groups: during a ten-day period, they either performed five training sessions during which they continuously avoided pictures of chocolate-containing foods (upward swipes) and approached pictures of neutral objects (downward swipes; *experimental group*), performed five training sessions during which they approached and avoided food and neutral stimuli equally often (*placebo control group*), or did not perform an approach–avoidance training (*inactive control group*). All participants completed an AAT and reported their craving for and consumption of chocolate-containing foods before and after the ten-day period. Furthermore, previous studies found short-term effects of approach–avoidance training on food consumption (e.g., reduced chocolate muffin consumption in a taste test immediately after an avoidance training session [18]). To capture such short-lived effects, participants reported their craving for and consumption of chocolate-containing foods on each evening during the ten-day period. This allowed us to examine both short-term training effects by comparing chocolate craving and consumption on intervention versus rest days during the ten-day period and longer-term training effects by comparing pre- versus posttest values before and after the ten-day period.

We tested the following, preregistered hypotheses (https://aspredicted.org/pt9df.pdf):

(1) Similar to findings showing that an approach bias modification training decreased approach bias towards high-calorie foods [4], we expected that approach bias towards chocolate-containing foods would decrease from pre- to posttest only in the experimental group, but not in the two control groups.

(2) Similar to findings showing that self-monitoring of snacking decreases snack food consumption [19], we expected that self-reported chocolate craving and consumption in the past ten days would decrease from pre- to posttest in all three groups, as all participants were confronted with their chocolate consumption behavior during the study. However, due to craving- and consumption-reducing effects of approach–avoidance trainings found in previous studies [4, 18], we expected that these decreases would be larger in the experimental group than in the placebo control group and the inactive control group.

(3) Performing reaction time tasks involving palatable food pictures usually increases food craving from immediately before to immediately after the task [20, 21]. Therefore, we

expected that performing a chocolate-related AAT would induce chocolate craving, that is, current chocolate craving would be increased immediately after having performed the task compared to before. At pretest, we expected that these chocolate craving increases during the task would be similar in all three groups. As previous findings indicate that approach–avoidance trainings can decrease such food cue-induced craving [4], we expected that task-induced chocolate craving would be attenuated at posttest in the experimental group, but not in the inactive control group. As participants in the placebo control group were confronted with the chocolate pictures more often than participants in the inactive control group, we expected that the placebo would show an attenuation of task-induced chocolate craving at posttest as well, due to habituation. Finally, we hypothesized that current hunger would be unaffected by the intervention, that is, would be similar across groups and measurements.

(4) Given that short-term effects on food consumption have been reported in approach bias modification studies (i.e., reduced consumption after a training session [18]), we expected that chocolate craving and consumption would be reduced on intervention days compared to rest days in the experimental group and this difference would be larger than in the placebo control group.

In addition to these preregistered analyses, we also explored changes in body mass index and body fat mass as a function of group, examined whether any effects were moderated by baseline levels of trait chocolate craving and restrained eating, and tested whether groups differed in awareness of the study's aims.

Methods

Participants

A power analysis was conducted with G*Power version 3.1.9.2 for repeated measures analysis of variance with a within–between interaction. This revealed that a sample size of $N = 102$ (i.e., $n = 34$ participants per group) would be sufficient to detect a small effect ($f = 0.1$), given an alpha level of .05, power of .80, three groups, two measurements, and a correlation of $r = .80$ between repeated measures.

Participants were recruited at the University of Salzburg and through a local job advertisements website. Inclusion criteria were speaking fluent German, being between 18 and 50 years old, not being pregnant, and not having participated in similar studies in our laboratory. Recruitment advertisements also indicated that participants should be regular chocolate eaters (i.e., several times per week) and should not be underweight or currently dieting. One-hundred and seventeen individuals responded to the advertisements. Nine participants were excluded before enrollment: Seven participants did not meet inclusion criteria (current pregnancy ($n = 1$), non-German-speaking ($n = 2$), already participated in similar studies in our laboratory ($n = 4$)) and two participants indicated that they recently decided to refrain from eating chocolate due to lactose intolerance and health reasons ($n = 2$; Figure 1). Of the remaining 108 individuals, two did not participate due to technical problems and one discontinued participation (Figure 1). The final sample comprised 105 participants (85.7% female, $n = 90$) with a mean age of 23.4 years ($SD = 5.07$) and a mean body mass index of 23.3 kg/m^2 ($SD = 4.14$). The majority of participants had German (52.4%, $n = 55$) or Austrian (40%, $n = 42$) citizenship and were university students (94.3%, $n = 99$).

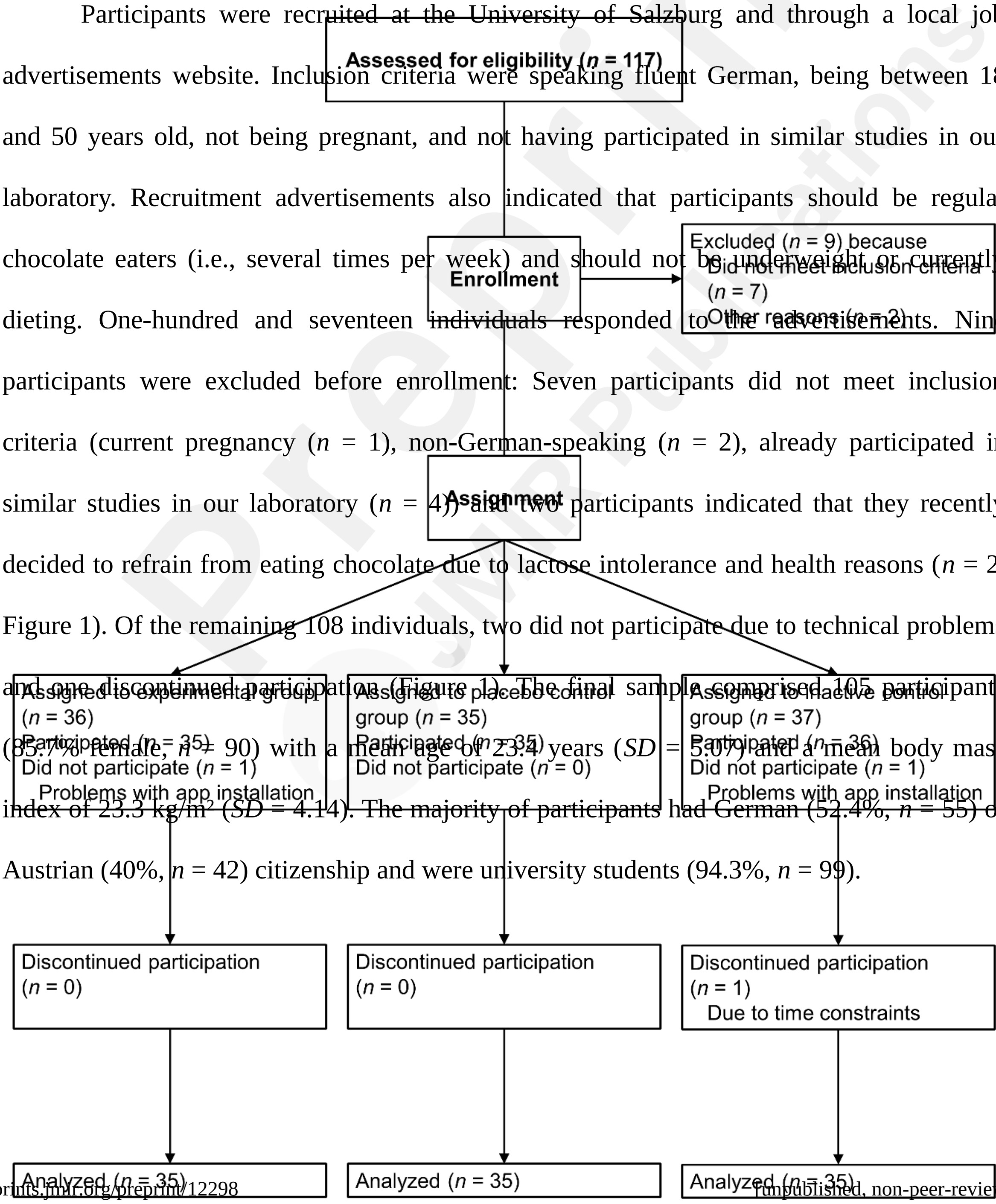

Figure 1. Flow of participants throughout the study. Note that while sample size was *n* = 105 for the majority of analyses, sample size was *n* = 104 for analyses involving body mass index at posttest and *n* = 102 for analyses involving body fat mass at posttest, due to missing data.

Materials

Approach–avoidance task (AAT). An AAT was employed to examine whether approach bias towards chocolate-containing foods changed from pre- to posttest as a function of group. The task was programmed in unity (Unity Technologies, San Francisco, CA, United States) and run on a five-inch SAMSUNG Galaxy J3 smartphone (Samsung Electronics Austria GmbH, Vienna, Austria). Sixteen pictures of chocolate-containing foods and 16 pictures of non-edible objects were taken from the food–pics database [22]. Pictures were matched regarding color, size, brightness, contrast, complexity, recognizability, and familiarity, and have previously been used in a joystick-based AAT with which an approach bias towards food was found [23]. The task consisted of two blocks: participants were instructed to swipe pictures of food upwards (= “away from yourself”) and swipe pictures of objects downwards (= “towards yourself”) with the thumb of their dominant hand in one block and vice versa in the other block (block order was counterbalanced across participants). Within each block, each picture was presented twice in randomized order. Thus, participants pulled food, pushed food, pulled objects, and pushed objects in 32 trials each, totaling 128 trials. In each trial, one picture appeared in the center of the smartphone screen. Similar to joystick-based AATs [24], a zoom effect was employed: picture size increased when the picture was swiped downwards and decreased when the picture was swiped upwards. The picture then disappeared when reaching the border of the screen and the next trial started.

Sociodemographic and anthropometric data. Participants indicated their age, sex, handedness, education, and nationality. Body height (in cm) was measured with a wall-mounted stadiometer. Body weight (in kg) and fat mass (in %) were measured with the OMRON Body Composition Monitor BF511 (OMRON Healthcare Europe B.V., Hoofddorp, The Netherlands).

Chocolate consumption. To examine whether chocolate consumption changed from pre- to posttest as a function of group, participants responded to the question “How often did you consume chocolate-containing foods in the past ten days?”. Responses were recorded on a rating slider anchored 0 = *not at all* and 100 = *very often*.

Food Cravings Questionnaire-Trait-reduced (FCQ–T–r). The German, chocolate-adapted version of the FCQ–T–r [25] was used to examine whether groups differed at pretest, whether pretest scores moderated any intervention effects, and whether scores changed from pre- to posttest as a function of group. Participants are usually instructed to indicate how frequently each statement is true for them in general. However, to fit the purpose of the current study, participants were instructed to indicate how frequently each statement was true for them in the past ten days. The scale has 15 items (e.g., “If I am craving chocolate, thoughts of eating it consume me.”, “It is hard for me to resist the temptation to eat chocolate that is in my reach.”) which are scored from 1 = *never* to 6 = *always*. Internal reliability was α = .894 at pretest and α = .921 at posttest.

Food Cravings Questionnaire-State (FCQ–S). The German, chocolate-adapted version of the FCQ–S [25] was used to measure current chocolate craving and hunger before and after the AAT. The scale has 15 items (12 items for the chocolate craving subscale and 3 items for the hunger subscale) which are scored from 1 = *strongly disagree* to 5 = *strongly agree*. Internal reliabilities of the chocolate craving subscale ranged between α = .873 and α = .930 and internal reliabilities of the hunger subscale ranged between α = .835 and α = .917 in the current study.

Restraint Scale. The German version of the Restraint Scale [26] was used to examine whether groups differed in dietary restraint and whether dietary restraint moderated any intervention effects. The scale has ten items which are scored from 0 to 4 (items 1–4 and 10) and 0 to 3 (items 5–9) with different response options. Internal reliability was α = .715 in the current study.

Dutch Eating Behavior Questionnaire (DEBQ). The German version of the DEBQ’s restrained eating subscale [27] was used to examine whether groups differed in dietary restraint and whether dietary restraint moderated any intervention effects. The scale has ten items which are scored from 1 = *never* to 5 = *very often*. Internal reliability was α = .879 in the current study.

Eating Disorder Examination–Questionnaire 8 (EDE–Q8). The German version of the EDE–Q8 [28] was used to examine whether groups differed in eating disorder symptomatology. The scale has eight items which are scored from 0 = *no days*/*never*/*not at all* to 6 = *every day*/*every time*/*very much*. Internal reliability was α = .883 in the current study.

End-of-day questions. On each evening during the ten-day period between pre- and posttest, participants answered questions on their smartphone using the application PsyDiary (MultimediaTechnology, Puch, Austria). Chocolate craving intensity was assessed with the question “How strong was your desire for chocolate-containing foods today (on average)?”. Answers were recorded on a rating slider anchored 0 = *very weak* and 100 = *very strong*. Chocolate craving frequency was assessed with the question “How often did you have a desire for chocolate-containing foods today?”. Answers were recorded on a rating slider anchored 0 = *not at all* and 100 = *very often*. Chocolate consumption quantity was assessed with the question “How many chocolate-containing foods did you consume today?”. Answers were recorded on a rating slider anchored 0 = *none* and 100 = *a great many*. Chocolate consumption frequency was assessed with the question “How often did you consume chocolate-containing foods today?”. Answers were recorded on a rating slider anchored 0 = *not at all* and 100 = *very often*.

Debriefing questions. Awareness of the study’s aims was assessed with the questions “Do you think that the aim of this study was to assess your behavior in relation to chocolate?” and “Do you think that the aim of this study was to change your behavior in relation to chocolate?”. Response options for both questions were *yes*, *no*, and *I don’t know*.

Procedure

The study was approved by the ethical review board of the University of Salzburg and study design and hypotheses were preregistered at https://aspredicted.org. The study was advertised as a study on “automatic reactions to chocolate-containing foods in daily life”. That is, participants were not informed that the aim of the study was to change chocolate craving and consumption. Participants were randomly assigned to one of the three groups and were tested in the laboratory individually.

Pretest. At pretest, participants signed informed consent and completed the FCQ–T–r, the question on chocolate consumption in the past ten days, and the FCQ–S. Next, participants practiced the swipe movements in two blocks with ten trials each (which included pictures of animals and household items that were not used in the main task) and then completed the AAT. Afterwards, they completed the FCQ–S again, responded to the sociodemographic questions, and completed the Restraint Scale, the DEBQ, and the EDE–Q8. Subsequently, body height, weight, and fat mass were measured. Finally, participants installed the applications and the experimenter explained their use, the remaining study procedures and discussed any open questions. At the end of the day of the pretest, participants received the first prompt (i.e., end-of-day questions) to familiarize them with the application (these data were discarded from analyses).

Intervention period. During the ten-day period between the pre- and posttest, all participants received the end-of-day questions on each evening at 9 p.m. and could respond to the questions until 10 p.m. The experimental group additionally performed five training sessions (one session on five days each). Training sessions were similar to the AAT used at pre- and posttest, except that pictures of food were always swiped upwards and pictures of objects were always swiped downwards (i.e., there was no reversal of instructions between blocks). The placebo control group also performed five training sessions (one session on five days each). Here, training sessions were equal to the AAT used at pre- and posttest, that is, pictures of food and objects were swiped up- or downwards equally often. In both the experimental and placebo control group, intervention and rest days were pseudorandomized with a maximum of three consecutive intervention or rest days. On intervention days, the training session was available between 12 noon and 8 p.m. (reminders were sent every two hours). The inactive control group did not perform any training sessions.

Posttest. At posttest, participants again completed the FCQ–T–r, the question on chocolate consumption in the past ten days, and the FCQ–S, performed the AAT, and then completed the FCQ–S again in the laboratory. Finally, they completed the debriefing questions and body weight and fat mass were measured. Participation was reimbursed with course credits or €40. The amount of course credits or money was reduced when participants did not complete all signals (i.e., training sessions or end-of-day questions).

Data analyses

Randomization check and compliance. We compared groups regarding baseline characteristics with analyses of variance (age, body mass index, body fat mass, chocolate consumption, FCQ–T–r scores, Restraint Scale scores, DEBQ scores, EDE–Q8 scores) and Fisher's Exact Tests (sex, handedness, education, nationality). Furthermore, we compared groups regarding the number of completed training sessions (in %) and completed end-of-day questions (in %) with Kruskal–Wallis Tests.

Hypothesis 1. Erroneous trials (e.g., swipes in the wrong direction) were excluded from analyses. These accounted for 7.27% of all trials at pretest and 10.4% of all trials at posttest. The number of valid trials did not differ between groups (Kruskal–Wallis Tests: pretest p = .245, posttest p = .225). Due to the task setup, we were able to differentiate between two different reaction times: the time between picture appearance and participants' first touch on the screen (*touching time*) and the time between participants' first touch on the screen and picture disappearance (*dragging time*). Bootstrapped split-half reliability estimates for each condition (pull food, push food, pull objects, push objects) were obtained using the R package *splithalf* [29] performing 5000 random splits. Reliability estimates for touching time ranged between r = .70–.77 (Spearman–Brown-corrected r_{sb} = .82–.87) at pretest and between r = .79–.81 (Spearman–Brown-corrected r_{sb} = .88–.90) at posttest. Reliability estimates for dragging time ranged between r = .69–.82 (Spearman–Brown-corrected r_{sb} = .82–.90) at pretest and between r = .63–.83 (Spearman–Brown-corrected r_{sb} = .77–.90) at posttest.

In line with joystick-based AAT studies [24] median reaction times were calculated. As outlined in the preregistration, 3 × 2 × 2 × 2 analyses of variance for repeated measures were calculated with median reaction time data as dependent variables, *group* (experimental vs. placebo control vs. inactive control) as between-subjects factor, and *measurement* (pre- vs.

posttest), *stimulus* (food vs. objects), and *direction* (pull vs. push) as within-subjects factors. This was done separately for touching time and for dragging time (which was not explicitly specified in the preregistration).

Hypothesis 2. As outlined in the preregistration, 3 × 2 analyses of variance for repeated measures were calculated with self-reported chocolate consumption and FCQ–T–r scores as dependent variables, *group* (experimental vs. placebo control vs. inactive control) as between-subjects factor, and *measurement* (pre- vs. posttest) as within-subjects factor.

Hypothesis 3. As outlined in the preregistration, 3 × 2 × 2 analyses of variance for repeated measures were calculated with FCQ–S scores (current chocolate craving and hunger) as dependent variables, *group* (experimental vs. placebo control vs. inactive control) as between-subjects factor, and *measurement* (pre- vs. posttest) and *task* (before vs. after the task) as within-subjects factors.

Hypothesis 4. Responses to the end-of-day questions on intervention days on which participants did not complete the training session were excluded from analyses. These accounted for 47 signals (6.71%) of the possible 700 signals (10 days × 70 participants [experimental + placebo control group]). As outlined in the preregistration, we applied linear mixed models using the R package *lme4* [30] to analyze the nested, longitudinal structure of the data. *Days* (0 = rest day, 1 = intervention day; Level 1) and *group* (0 = experimental group, 1 = placebo control group; Level 2) and their cross-level interaction *group* × *days* were used as predictors for chocolate craving intensity/frequency and for chocolate consumption quantity/frequency. We further explored whether pretest scores of the FCQ–T–r, Restraint Scale, and DEBQ at Level 2 would modulate any effects. The Level 1 predictor *days* was entered uncentered to the models and the Level 2 predictors *group*, *FCQ–T–r*, *Restraint Scale*, and *DEBQ* were grand-mean centered. The intercepts of all models were allowed to vary randomly.

Exploratory analyses. Analyses of variance for repeated measures with *group* (experimental vs. placebo control vs. inactive control) as between-subjects factor and *measurement* (pre- vs. posttest) as within-subjects factor were calculated to examine changes in body mass index and body fat mass as a function of group. Moderation analyses were calculated with PROCESS [31] to examine whether FCQ–T–r scores at pretest, Restraint Scale scores, and DEBQ scores moderated any effects of group on chocolate consumption, body mass index, and body fat mass at posttest while controlling for pretest values. Restraint Scale scores and DEBQ scores were also tested as moderators of effects of group on FCQ–T–r scores at posttest while controlling for FCQ–T–r scores at pretest. Fisher's Exact Tests were calculated to compare groups regarding the two debriefing questions. These analyses were not included in the preregistration protocol.

Results

Randomization check and compliance

Groups did not differ in any baseline characteristics (Table 1). Compliance was high for both completion of the training sessions (86.6%) and completion of the end-of-day questions (85.8%) and did not differ between groups (Table 1).

Table 1

Means and frequencies of study variables at pretest and compliance rates during the intervention phase as a function of group

N = 105	Experimental group (*n* = 35)	Placebo control group (*n* = 35)	Inactive control group (*n* = 35)	Test statistics
Age (years)	*M* = 22.7 (*SD* = 3.36)	*M* = 24.1 (*SD* = 6.13)	*M* = 23.5 (*SD* = 5.37)	$F_{(2, 102)}$ = 0.64, *p* = .531, η_p^2 = .012
Sex (female)	*n* = 30 (85.7%)	*n* = 32 (91.4%)	*n* = 28 (80.0%)	χ^2 = 1.84, *p* = .449, ϕ = .133
Handedness (right-handed)	*n* = 28 (80.0%)	*n* = 32 (91.4%)	*n* = 33 (94.3%)	χ^2 = 3.52, *p* = .226, ϕ = .194
Education (students)	*n* = 33 (94.3%)	*n* = 32 (91.4%)	*n* = 34 (97.1%)	χ^2 = 1.09, *p* = .869, ϕ = .101
Nationality (German)	*n* = 16 (45.7%)	*n* = 21 (60.0%)	*n* = 18 (51.4%)	χ^2 = 3.54, *p* = .470, ϕ = .184
Body mass index (kg/m²)	*M* = 23.5 (*SD* = 4.90)	*M* = 23.3 (*SD* = 3.62)	*M* = 23.0 (*SD* = 3.89)	$F_{(2, 102)}$ = 0.16, *p* = .856, η_p^2 = .003
Body fat mass (%)	*M* = 31.6 (*SD* = 9.91)	*M* = 32.8 (*SD* = 7.52)	*M* = 29.5 (*SD* = 9.00)	$F_{(2, 102)}$ = 1.29, *p* = .280, η_p^2 = .025
Chocolate consumption (self-report)	*M* = 55.6 (*SD* = 20.9)	*M* = 61.5 (*SD* = 21.3)	*M* = 58.1 (*SD* = 22.8)	$F_{(2, 102)}$ = 0.65, *p* = .522, η_p^2 = .013
Food Cravings Questionnaire–Trait–reduced (chocolate version)	*M* = 41.4 (*SD* = 8.54)	*M* = 41.2 (*SD* = 10.5)	*M* = 44.2 (*SD* = 12.2)	$F_{(2, 102)}$ = 0.90, *p* = .411, η_p^2 = .017
Restraint Scale	*M* = 11.5 (*SD* = 5.05)	*M* = 12.0 (*SD* = 4.53)	*M* = 11.7 (*SD* = 4.69)	$F_{(2, 102)}$ = 0.11, *p* = .893, η_p^2 = .002
Dutch Eating Behavior	*M* = 2.04 (*SD* = 0.80)	*M* = 2.03 (*SD* = 0.60)	*M* = 2.16 (*SD* = 0.65)	$F_{(2, 102)}$ = 0.38, *p* = .682,

Questionnaire (restrained eating subscale)				η_p^2 = .007
Eating Disorder Examination–Questionnaire 8	*M* = 0.97 (*SD* = 1.11)	*M* = 1.00 (*SD* = 0.72)	*M* = 1.23 (*SD* = 1.08)	$F_{(2, 102)}$ = 0.75, *p* = .477, η_p^2 = .014
Training sessions compliance (%)	*M* = 89.1 (*SD* = 17.7)	*M* = 84.0 (*SD* = 19.3)	—	Kruskal–Wallis Test *p* = .221
End-of-day questions compliance (%)	*M* = 88.0 (*SD* = 17.5)	*M* = 88.6 (*SD* = 16.1)	*M* = 80.6 (*SD* = 25.6)	Kruskal–Wallis Test *p* = .393

Hypothesis 1

Touching time. A main effect of *direction* ($F_{(1,102)} = 13.3$, $p < .001$, $\eta_p^2 = .115$) indicated that participants touched the target stimuli faster in pull trials (*M* = 599, *SD* = 55.3) than in push trials (*M* = 606, *SD* = 56.0). There were significant main effects of *measurement* and *stimulus* and interaction effects *measurement* × *stimulus* and *group* × *measurement* (all *p*s < .001), which were qualified by a significant interaction *group* × *measurement* × *stimulus* ($F_{(2,102)} = 4.82$, $p = .010$, $\eta_p^2 = .086$). However, as this interaction effect was small, did not include any direction effects, and post-hoc comparisons were inconclusive, it was not further interpreted. More information and a graphical depiction can be found in the supplementary material (Figure S1). There was no significant main effect of *group* ($F_{(2,102)} = 2.17$, $p = .119$, $\eta_p^2 = .041$) and no other significant interaction effects (all *p*s > .158).

Dragging time. A main effect of *stimulus* ($F_{(1,102)} = 9.46$, $p = .003$, $\eta_p^2 = .085$) indicated that participants swiped food pictures (*M* = 248 ms, *SD* = 44.5) faster than object pictures (*M* = 252 ms, *SD* = 53.3). There were no other significant main or interaction effects (all *p*s > .053).

Hypothesis 2

Chocolate craving. A main effect of *measurement* ($F_{(1,102)} = 11.7$, $p = .001$, $\eta_p^2 = .103$) indicated that FCQ–T–r scores decreased from pretest (*M* = 42.3, *SD* = 10.5) to posttest (*M* =

40.1, *SD* = 11.7). There was no significant main effect of *group* ($F_{(2,102)}$ = 0.48, *p* = .618, η_p^2 = .009) and no significant interaction *group* × *measurement* ($F_{(2,102)}$ = 0.79, *p* = .458, η_p^2 = .015).

Chocolate consumption. A main effect of *measurement* ($F_{(1,102)}$ = 10.3, *p* = .002, η_p^2 = .092) indicated that self-reported chocolate consumption decreased from pretest (*M* = 58.4, *SD* = 21.6) to posttest (*M* = 51.8, *SD* = 20.2). There was no significant main effect of *group* ($F_{(2,102)}$ = 0.35, *p* = .705, η_p^2 = .007) and no significant interaction *group* × *measurement* ($F_{(2,102)}$ = 0.84, *p* = .435, η_p^2 = .016).

Hypothesis 3

Current chocolate craving. A main effect of *task* ($F_{(1,102)}$ = 20.7, $p < .001$, η_p^2 = .169) indicated that FCQ–S craving scores increased from before (*M* = 28.0, *SD* = 7.55) to after the task (*M* = 29.5, *SD* = 8.65). A main effect of *measurement* ($F_{(1,102)}$ = 17.6, $p < .001$, η_p^2 = .147) indicated the FCQ–S craving scores decreased from pretest (*M* = 30.1, *SD* = 8.01) to posttest (*M* = 27.4, *SD* = 9.20). There was no significant main effect of *group* ($F_{(2,102)}$ = 1.06, *p* = .351, η_p^2 = .020) and no significant interaction effects (all *p*s > .462).

Hunger. A main effect of *task* ($F_{(1,102)}$ = 11.0, *p* = .001, η_p^2 = .098) indicated that FCQ–S hunger scores increased from before (*M* = 7.91, *SD* = 2.74) to after the task (*M* = 8.20, *SD* = 3.01). There was no significant main effect of *measurement* ($F_{(1,102)}$ = 1.36, *p* = .246, η_p^2 = .013), no significant main effect of *group* ($F_{(2,102)}$ = 2.46, *p* = .091, η_p^2 = .046), and no significant interaction effects (all *p*s > .433).

Hypothesis 4

Chocolate craving intensity and frequency. There was no significant effect of intervention versus rest days as a function of group (see Table S1 in the supplementary material). Higher FCQ–T–r scores at pretest related to higher chocolate craving intensity and frequency, independent of days and group (Table S2). Restrained eating did not relate to chocolate craving intensity or frequency and did not interact with days or group (Table S3,

Table S4).

Chocolate consumption quantity and frequency. There was no significant effect of intervention versus rest days as a function of group (Table S5). Higher FCQ–T–r scores at pretest related to higher chocolate consumption quantity and frequency, independent of days and group (Table S6). In addition, a significant *days* × *FCQ–T–r* interaction indicated that participants with high trait chocolate craving scores consumed chocolate-containing foods more frequently on intervention than on rest days, irrespective of group (Table S6). Restrained eating did not relate to chocolate craving quantity or frequency and did not interact with days or group (Table S7, Table S8).

Exploratory analyses

Body mass index. There were no significant main effects and no interaction effect *group* × *measurement* (all *p*s > .561).

Body fat mass. A main effect of *measurement* ($F_{(1,99)}$ = 4.43, *p* = .038, η_p^2 = .043) indicated that body fat mass decreased from pretest (*M* = 31.4, *SD* = 8.49) to posttest (*M* = 31.1, *SD* = 8.73). There was no significant main effect of *group* ($F_{(2,99)}$ = 0.80, *p* = .452, η_p^2 = .016) and no significant interaction *group* × *measurement* ($F_{(2,99)}$ = 0.30, *p* = .739, η_p^2 = .006).

Moderation analyses. There were no significant interaction effects between *group* and *FCQ–T–r*, *Restraint Scale*, and *DEBQ* scores at pretest (all *p*s > .243).

Debriefing questions. Ninety-three participants (88.6%) indicated that they thought the aim of the study was to assess their behavior in relation to chocolate, four participants (3.8%) did not think so, and eight participants (7.6%) indicated that they did not know. There were no significant differences between groups (χ^2 = 4.64, *p* = .300, ϕ = .224). Twenty-nine participants (27.6%) indicated that they thought the aim of the study was to change their behavior in relation to chocolate, 61 participants (58.1%) did not think so, and 15 participants (14.3%) indicated that they did not know. Here, responses did significantly differ between groups (χ^2 = 9.63, *p* = .043, ϕ = .317): more participants in the inactive control group (*n* = 26) did not think that the study's aim was to change their behavior than participants in both the experimental group (*n* = 18) and the placebo control group (*n* = 17), while the latter two groups did not differ from each other (based on follow-up *z*-tests using α = .05).

Discussion

The current study examined effects of a smartphone-based approach–avoidance intervention on approach bias towards chocolate-containing foods and chocolate craving/consumption relative to placebo and no training conditions. The three groups were well matched at baseline, treatment adherence was high (87% completed training sessions), and study attrition was low. All dependent measures evidenced good-to-excellent reliability. Yet, a smartphone-based AAT did neither reveal an approach bias towards chocolate-containing foods at baseline nor a modulation through training. In fact, chocolate craving and consumption decreased throughout the study period in all three groups. This self-report finding was corroborated in that participants in all groups lost body fat. Crucially, only a minority of participants thought that the current study's aim was to change their behavior, suggesting that these effects were not due to demand characteristics. Comparing chocolate craving and consumption on intervention versus rest days did not reveal any short-term effects of the training.

Measuring and modifying approach–avoidance tendencies with swipe movements

To the best of our knowledge, this is the first study that aimed at measuring and changing an approach bias towards food stimuli based on swipe movements on smartphones. While there are similar studies that examined effects of smartphone-based approach–avoidance trainings with swipe movements on procrastination and body dissatisfaction [12, 13], these studies did not measure effects of the training on approach–avoidance tendencies. Thus, the lack of finding and modifying an approach bias towards chocolate-containing foods may be related to an insensitivity of our newly developed task to detect such effects. However, several arguments speak against such an interpretation. First, we used the same stimuli with which an approach bias towards food was detected in a comparable sample with a joystick-based AAT [23]. Second, the AAT in the current study had moderate-to-good internal reliability [32] and, thus, unreliability of the task is unlikely to account for the current lack of findings. Third, increasing evidence indicates that the type of arm movements [flexion and extension; 33] or distance change [34] is not essential for measuring or modifying approach–avoidance inclinations. For example, it has been found that up- and downward movements or framing actions as approach and avoidance suffice to modify stimulus evaluations [35]. Nevertheless, future research needs to determine whether other techniques such as moving the smartphone towards and away with arm movements [36, 37] or using tilt movements [38] are better suited for detecting and changing approach–avoidance tendencies with smartphones. In addition, it has recently been found that combining approach–avoidance actions with affective feedback produced stronger changes in food choices than conventional approach–avoidance training [39]. Thus, using such consequence-based approach–avoidance trainings may similarly enhance training effects with smartphone-based implementations.

Effects of monitoring food intake

Another consideration is that—even if the approach–avoidance training had an effect—it may have been masked by the general decreases in outcome variables across the study period that were observed regardless of group assignment. Specifically, we included daily end-of-day-questions in the study design to be able to examine short-term effects (i.e., on the same day) of the single training sessions. However, these questions may have acted as a type of ecological momentary intervention [40]. For example, it has been shown that keeping a daily snack diary reduced snacking frequency, suggesting that cue monitoring suffices to decrease unhealthy food intake [irrespective of additional intervention modules; 41], potentially through increased awareness for one's eating behavior. In fact, it has been found that self-monitoring in terms of completing a record of snacking once per day in the evening decreased snack food consumption even in samples that are not particularly motivated to change their behavior [19]. Thus, we cannot fully exclude the possibility that the intervention may have effects—albeit small—on eating behavior that were masked by effects of monitoring food intake.

Limitations

Interpretation of results needs to consider the sample investigated in the current study. While we included both men and women with a body mass index ranging from underweight to obese, the majority of the sample were normal-weight women. It has been previously suggested that successful retraining of appetitive reactions and consumption behaviors may primarily be found in clinical samples [9]. While we investigated a non-clinical sample, it is worth noting that our participants had above-average mean scores (>40; Table 1) on the FCQ–T–r [mean scores were 35 in study 1 and 34 in study 2 in the validation studies; 25] and their eating behavior was clearly impacted throughout the study period (i.e., measures were sensitive to detect training-induced changes). This renders insufficient levels of trait chocolate craving as an explanation for the current findings unlikely.

Several other methodological considerations might account for the current results. For example, while we selected food stimuli with which we have previously detected an approach bias in a comparable sample using a joystick-based task [23], it may be that approach–avoidance trainings work better when using personalized stimuli, that is, pictures of foods that participants actually crave and consume regularly in their daily life. In related research on attentional bias, for example, it has been found that internal reliability of reaction time tasks can be increased when personalized stimuli are used [42]. Furthermore, we used relatively few training sessions (five), which may have been insufficient to produce meaningful changes in approach bias and eating behavior. However, evidence from joystick-based approach–avoidance trainings suggest that few sessions suffice to detect such effects in relation to alcohol [43]. Yet, other smartphone-based studies did indeed use more frequent training sessions [12, 13]. Thus, the number of training sessions required in smartphone-based approach–avoidance trainings need further examination. Finally, although we instructed participants regarding the meaning of upward and downward swipe movements, we did not assess whether they actually perceived the movements as pushing or pulling the pictures away from or towards themselves. Therefore, we cannot rule out the possibility that participants did not perceive the movements as intended, which could explain the lack of finding an approach bias and training effects.

Conclusions

Repeatedly avoiding chocolate-containing foods in terms of (zoom out) upward swipe movements on smartphones did not change behavior related to these foods in the current study. Due to several methodological considerations, there is an urgent need for future research that determines the most effective way of measuring and changing approach–avoidance tendencies in daily life. General decreases in chocolate craving and consumption as well as body fat mass in the current study may be due to the generally raised awareness of chocolate consumption throughout the study period. Thus, receiving daily prompts for monitoring food intake may be a cheap and efficient way to normalize food intake in individuals with eating disorders and facilitate weight loss in individuals with obesity.

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