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Comparison of different response devices to assess behavioral tendencies towards chocolate
in the Approach-Avoidance Task

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Abstract

Behavioral tendencies in the Approach-Avoidance Task (AAT) have mostly been assessed using a joystick as a response device. In recent years, other hardware devices such as tablets, smartphones, and computer mice have also been used. However, it remains unclear whether different response devices yield similar results and show comparable psychometric properties. The aim of the present study was to assess approach biases towards chocolate with different response devices and to compare their reliability and validity. Forty-five individuals with regular chocolate consumption completed three different AATs (joystick, computer mouse, touchscreen), each comprised of two blocks. In the compatible block of trials, chocolate-related pictures had to be pulled near while object-related pictures had to be pushed away. In the incompatible block of trials, instructions were reversed. Preregistered analyses revealed that participants were faster to pull than to push chocolate-related pictures relative to object-related pictures, indicating an approach bias for chocolate with no significant differences between response devices. Correlations among the three response devices were low to medium. Exploratory analyses revealed that approach biases were moderated by block order such that biases were only present and associated with craving (joystick AAT only) when the incongruent block was completed first. Internal consistencies of the bias score ranged between $r_{SB} = .67-.76$. Results of the present study point to the existence of an approach bias to chocolate regardless of response device, albeit each task seems to measure a different aspect of it. Order effects point to specific temporal dynamics in the acquisition of stimulus response (e.g., chocolate-pull) mappings that require further study.

Keywords: Behavioral Tendencies; Chocolate; Approach–Avoidance Task; Touchscreen; Mouse; Joystick

1. Introduction

Humans show a tendency to approach appetitive and to avoid negative stimuli (e.g., Cacioppo, Priester, & Berntson, 1993). Such behavioral tendencies can be assessed by means of approach-avoidance tasks (Roefs et al., 2011) such as the Stimulus Response Compatibility (SRC, De Houwer et al., 2001) and the joystick Approach-Avoidance Task (AAT, Rinck & Becker, 2007). During the SRC participants are instructed to move a manikin towards or away from specific stimuli via key press, for example, towards food-related stimuli and away from another category or vice-versa (e.g., Brignell et al., 2009; Neimeijer et al., 2019). Therefore, the SRC rather assesses symbolic approach-avoidance behavior. In order to capture motor behavior, the joystick AAT has often been applied, which assesses behavioral tendencies implicitly by means of arm movements. More specifically, participants are presented with various stimuli, for example, pictures of palatable food and objects, and instructed to react with either pushing or pulling a joystick. To disambiguate the impression of approach and avoidance visually, the joystick AAT incorporates a zoom function such that pictures are enlarged when pulled and diminished when pushed. Avoidance tendencies are inferred from faster pushing (i.e., arm extension) than pulling (i.e., flexion), approach tendencies from faster pulling than pushing (relative to control images). Typically, effects of picture content on behavioral tendencies have been measured indirectly such that the response direction was dependent on a non-affective dimension (e.g., tilt or format of pictures) and image content was task irrelevant. Although numerous studies have found evidence for implicit behavioral avoidance of negative and behavioral approach tendencies of positive stimuli using the indirect AAT (Loijen et al., 2020; Phaf et al., 2014), it has been shown that tasks with explicit instructions, where the picture content is task relevant, have yielded larger and more consistent effects (Kahveci et al., 2020; Kersbergen et al., 2015; Lender et al., 2018; Meule, Lender, et al., 2019; Phaf et al., 2014).

Aside from a number of mobile and virtual reality implementations (Kakoschke et al., 2018; Schroeder et al., 2016; Zech et al., 2020), recent studies have also used other hardware devices such as a computer mouse (e.g., Wittekind, Lüdecke, et al., 2019; Wittekind, Reibert, et al., 2019) or a touchscreen monitor (Kahveci et al., 2020; Meule, Lender, et al., 2019; Meule, Richard, et al., 2019) to assess behavioral tendencies. Computer mice are readily available which has advantages, for example, in online studies, and have been used in the smoking domain (Wittekind et al., 2015; Wittekind, Lüdecke, et al., 2019). However, data regarding the size and reliability of the mouse based AAT are scarce.

An advantage of the touchscreen monitor is that it might enable the assessment of more naturalistic movements. As Meule, Richard et al. (2019) have argued, food intake typically involves reaching out for and grasping food, a movement that is not appropriately represented with the joystick AAT. The joystick further introduces a ‘perspective ambiguity’ as it is not immediately clear whether it moves the participant back and forth (as in computer games) or the food. To address these two limitations, they transferred the principle of the joystick AAT to a touchscreen monitor: participants placed their dominant hand in the center of a touchscreen monitor, which triggered the presentation of chocolate-related or object-related pictures on the top/distal side or the bottom/proximal side of the vertically oriented screen. However, no approach bias for chocolate-related pictures was found. In a follow-up study the design was adapted so that it was possible to differentiate between the time it took participants to grab the pictures and the time it took to drag the pictures (Meule, Richard, et al., 2019). Although a bias for chocolate-related pictures was found for the grab movement, no bias emerged for the drag movement. In conclusion, several response devices have been used to measure the AAT bias, but no clear advantage for any of them has emerged and no study has yet compared them directly.

Knowledge on which response device is preferable for AAT bias assessment has methodological as well as practical implications. The implementation of distance change

differs between these response devices: While the joystick and the mouse AAT operate with virtual distance changes (zoom feature), the touchscreen AAT adds a physical distance change to this. Current theoretical debates have revolved around hard wired mappings of responses to stimuli (i.e., arm flexor = approach = compatible with positive stimuli, e.g., Cacioppo et al., 1993) vs. more flexible mappings of valence on a certain response (i.e., joystick push+zoom out feature = avoidance vs. joystick pull+zoom in = approach). Thus, it will be of interest which implementation of distance change yields the clearest bias (in size, reliability and validity). Additionally, it remains an open question whether different response devices provide comparable results and psychometric properties (i.e., reliability, validity). Consequently, both practical and theoretical considerations call for a comparison of the response devices that have been used in previous research.

The aim of the present study was to compare three different response devices (joystick AAT, mouse AAT, touchscreen AAT) in a within-subject design to assess behavioral approach tendencies towards chocolate in individuals with regular chocolate consumption. Additionally, the three different response devices were compared regarding their reliability and validity. To assess the validity of the tasks, different validation data was assessed (e.g., craving for chocolate, ad-libitum chocolate consumption, body mass index [BMI]). Based on previous research (e.g., Lender et al., 2018) we tested our preregistered hypothesis that participants would show an approach bias for chocolate-related pictures; however, as multiple AAT tasks with different response devices have never been administered within one study, we did not have a directed hypothesis which response device would provide the largest, most valid and most reliable bias. We further tested our preregistered hypothesis that the bias measures derived from the three AAT tasks would correlate positively with each other. We additionally assume that the approach bias for chocolate would be positively correlated with BMI, trait and state chocolate craving as well as ad libitum chocolate consumption. Regarding BMI, it has been shown that more frequent chocolate consumption is associated with a

significantly greater prospective weight gain over time (Greenberg & Buijsse, 2013) and that obese individuals show approach biases for food-cues (e.g., Kemps & Tiggemann, 2015). These findings suggest that a higher BMI is related to approach biases for chocolate-related pictures; however, findings of other studies suggest that a higher BMI is related to difficulties avoiding sweet/high calorie foods (e.g., Havermans et al., 2011; Maas et al., 2017).

2. Methods

2.1 Participants

Participants were recruited between February and July 2019 at the LMU Munich by means of Facebook, advertisements at the University campus, and through personal contact. Inclusion criteria were age between 18 and 40 years, regular chocolate consumption (at least twice/week), no food consumption within the last two hours prior to study participation, and sufficient German language skills. The age range was restricted as it has been shown that among adult individuals, the age group 18-39 years shows the highest consumption of unhealthy foods (Bel et al., 2019). The following exclusion criteria were applied: lifetime history of a severe psychiatric (e.g., schizophrenia, bipolar disorder) or neurological disorder (e.g., multiple sclerosis), any food intolerance, vegan diet, and acute suicidality.

2.2 Materials

Sociodemographic and anthropometric data. Participants indicated their date of birth, sex, body weight (in kilograms), body height (in meters), handedness (self-report), whether vision was corrected (e.g., glasses, lenses), and their highest school education.

Timeline follow-back (TLFB). In order to assess the consumption of chocolate and chocolate containing sweets, participants were instructed on paper to indicate how much

chocolate (in grams) and/or pieces of chocolate containing sweets (in pieces) they consumed each day during the last seven days.

Dutch Eating Behavior Questionnaire (DEBQ). Eating styles were assessed with the German version of the DEBQ (Grunert, 1989; van Strien et al., 1986). The 30-item scale consists of the subscales emotional eating, external eating, and restraint; items are scored on a 5-point Likert scale ranging from 1 (*never*) to 5 (*very often*). Internal consistency can be considered good (Cronbach's $\alpha = .89$) in the present study.

Perceived Success in the Self-Regulation of Dieting Scale (PSRS). To differentiate between successful and unsuccessful dieters, the 3-item PSRS was used (Fishbach et al., 2003; psychometric properties of German version: Meule et al., 2012). Items are answered on a scale ranging from 1 (*not successful, not difficult*) to 7 (*very successful, very difficult*). Internal consistency in the present sample was Cronbach's $\alpha = .661$. Three additional items were administered to identify participants who were dieting ("Are you restricting your food intake in order to change your figure or body weight [e.g., by trying to eat less or by avoiding certain kinds of food]?") and to measure the importance of being slim ("How important is it for you to monitor your weight?", "How important is it for you to be slim?").

Food Cravings Questionnaire-Trait-reduced (FCQ-T-r). Craving for chocolate in general was assessed with the German 15-item version of the FCQ-T-r, consisting of the subscales lack of control and thoughts about chocolate (Meule & Hormes, 2015). Items were re-phrased to specifically assess craving for chocolate. Participants had to indicate how often each statement was true for them in general (1 = *never* to 6 = *always*). Internal consistency was Cronbach's $\alpha = .93$ for the total scale, $\alpha = .91$ for the subscale lack of control, and $\alpha = .89$ for the subscale thoughts about chocolate in the present study.

Food Cravings Questionnaire-State (FCQ-S). To assess momentary craving specifically for chocolate the German 15-item version of the FCQ-S was administered (Meule & Hormes, 2015). Participants had to indicate whether they agree with each item (1 =

strongly disagree to 5 = *strongly agree*). The FCQ-S comprises the subscales chocolate craving (item 1-12) and current hunger (item 13-15). Cronbach's α for the total scale was $\alpha = .89$, for the craving subscale $\alpha = .90$, and for the hunger subscale $\alpha = .83$.

Approach–Avoidance Task (AAT). In order to assess implicit behavioral approach tendencies, three AATs were administered with different response devices (mouse, joystick, touchscreen). Each AAT was programmed using unity (<https://unity3d.com>) and included 10 chocolate-related and 10 object-related pictures. All pictures were selected from the Food-pics-database (Blechert et al., 2019) and matched by eye as to valence, perceptibility, concreteness, and representativeness. In total, 30 chocolate-related and 30 object-related pictures were selected to compile three parallel picture sets such that each AAT was administered with a different picture set (see Supplementary Material Table S1). Object-related pictures comprise different categories, for example, household objects (e.g., corkscrew), office supply (e.g. envelop), or kitchen accessories (e.g., cutting board, for examples see Supplementary Material). Although a negative reference category has also been used in previous research (e.g., Browning et al., 2010; Hoppitt et al., 2010; MacLeod et al., 2002), effects might be over-estimated as the opposite pattern of response would be expected (approach bias for positive, avoidance bias for negative stimuli). Therefore, a neutral control category was included in the present study. Pictures were presented with a resolution of 96 dpi (619x469 pixels) on a 24'' monitor (AAT_{mouse}, AAT_{joystick}) or on a 23'' touchscreen monitor (AAT_{touch}, iiyama ProLite T2336MSC-B2). The order of the three different AATs, block order, and stimulus set was counterbalanced across participants (see Supplementary Material Table S2).

Each 'feature relevant' AAT consisted of two blocks with reversed instructions: in the compatible block participants were instructed to pull chocolate-related pictures towards themselves (=approach) and to push object-related pictures away (=avoidance) while instructions were reversed in the incompatible block. Each participant received the same

block order in the three AATs. Within each block, each picture was randomly presented three times yielding 60 trials per block. Prior to the experiment participants completed six practice trials during which pictures of butterflies had to be pulled and pictures of leaves to be pushed (i.e., 126 trials in total). In each trial, pictures were presented in the center of the (touch)screen and depending on the device

AAT_{touch}. The touchscreen monitor was positioned in portrait orientation on the table with an angle of 20° off the horizontal table top. At the beginning of each trial, a hand symbol appeared which had to be touched with at least three fingers. Then, a picture appeared under the participant's hand and depending on instructions, pictures had to be moved to the bottom (= towards the participant, pull) or to the top of the screen (= away from the participant, push). The participant's hand had to touch the screen throughout the trial (if the hand was lifted, the trial was counted as an error). Hand movement was directly coupled to image size and position (i.e., no dynamic swipe). When the object reached the final edge of the screen, it disappeared and the next trial was initiated (see Figure 1b).

AAT_{Mouse}. This task was performed using a standard computer mouse. Each trial started with the presentation of a fixation cross, participants were instructed to position the mouse cursor on the fixation cross and to press the left mouse button. Pressing the button led to the appearance of the picture. Depending on instructions, the mouse had to be pulled or pushed. To be consistent across AAT devices, participants were instructed to press and hold down the left mouse button throughout the trial. Mouse movement was directly coupled to image size and the picture disappeared when it reached its maximum size (and was moved in the correct direction). After each trial, participants had to put the mouse back to a neutral position (marked on mousepad, see Figure 1a). During the entire trial the mouse cursor was invisible.

AAT_{Joystick}. The set-up of the joystick AAT was similar to the mouse AAT except that a joystick (ThrustMaster T.16000M) was used. Again, a central fixation cross was presented; as soon as participants pressed the trigger a picture appeared on the screen and participants had

to push/pull the joystick depending on instructions. The cursor was invisible and the trigger had to be pressed throughout the entire trial (see Figure 1a).

Picture Rating. Participants were asked to rate all pictures (i.e., 30 chocolate-related, 30 object-related) regarding valence (visual analogue scale ranging from *not pleasant at all* to *very pleasant*). Of the chocolate-related pictures, a subset of 10 pictures was randomly selected and had to be rated as to palatability (*not palatable at all* to *very palatable*) and craving (*not strong at all* to *very*). The latter pictures were also presented during the AAT tasks.

Chocolate consumption. A taste test was administered to assess ad-libitum chocolate consumption. Participants were told that Ritter Sport, a German chocolate company, wanted to release a new chocolate brand containing xylitol instead of refined sugar. Two bowls (with 100g chocolate each) were placed in front of participants who were told that one bowl would contain the traditional and the other one the new chocolate (however, both bowls contained the same type of chocolate). Importantly, the experimenter did not refer to a specific bowl such that participants were “blinded”. Participants were asked to rate the chocolate regarding different criteria on a 5-point scale (e.g., smell, taste, consistency, sweetness, quality). The experimenter left the room during the taste test and participants were granted 10 min to provide the ratings. Subsequently, the amount of consumed chocolate was determined (bowls were weighed pre and post taste test with a precision scale [DIPSE TP], precision 0.01g).

2.3 Procedure

The study was approved by the Ethics committee of the Faculty of Psychology and Education at LMU Munich (project number: 61_Wittekind_b), was conducted in accordance with the Declaration of Helsinki, and was pre-registered at <https://aspredicted.org/t6g6a.pdf>. All participants gave written informed consent prior to participation. Participants were tested individually between 2 pm and 6 pm. First, sociodemographic and anthropometric

information were assessed. Additionally, at the end of the sociodemographic interview inclusion and exclusion criteria were carefully checked. The criterion of not having eaten prior to study participation was assessed via self-report. If participants met inclusion criteria and indicated to eat chocolate/chocolate containing food at least twice a week (as assessed with the TLFB), the assessment continued. Participants were administered eating-related questionnaires (DEBQ, PSRS, FCQ-T, FCQ-S) via Inquisit 5 (<https://millisecond.com>). Then, three different response devices of the assessment AAT were administered in counterbalanced order. After the first and the second AAT, participants' state chocolate craving was assessed with a single item of the FCQ-S ("I have an intense desire to eat chocolate"), after the third AAT participants were again asked to complete the whole FCQ-S. At the end of the session, the picture rating and the taste test were carried out. Finally, participants were thanked for their participation and reimbursed by receiving 8€ per hour or partial course credit (session length was ~ 75 min).

2.4 Data analysis

Our hypotheses and statistical approach were specified in a pre-registration (<https://aspredicted.org/t6g6a.pdf>). Any additional data analyses are identified as exploratory and discussed appropriately. We followed the pre-registered ANOVA analyses and first present results of these analyses. However, in order to check whether the relevant interactions of Picture Type x Response Direction and Picture Type x Response Direction x Response Device were influenced by Order of Picture Set, Order of Response Device, and Block Order, a 6-way ANOVA was also conducted (see Supplementary Material for results). These exploratory analyses revealed that AAT effects depended on Block Order (but not on picture set or order of response device), therefore, results are presented in the main manuscript under the section header "exploratory analyses".

Before reaction times (RTs) were analyzed, error trials were removed whereby two different kinds of error trials were defined: “typical” error trials (=error 1) were defined as trials in which participants moved the joystick, the mouse, or their hand in the wrong direction or changed direction throughout the trial. These trials (8% of trials) were removed. Subsequently, trials with initial RTs (= time between picture onset and start of movement) < 200ms, > 2000ms, and > 3 SD above participants’ mean were excluded (= error 2, 2%). Additionally, data of participants with >35% error 1 trials (i.e., wrong direction, change of direction throughout trial) in any condition of any task were excluded (the mean number of errors per condition, response direction, and task is depicted in Table S1, Supplementary Material). Based on these criteria nine participants had to be excluded leaving a final sample of 45 participants. For the remaining trials and participants, the median RTs for two different kinds of RTs were determined: (1) the time between picture onset and start of movement (initial RT), (2) the time between picture onset and end of the movement (final RT). To test whether there were differences in biases, analyses of variance (ANOVA) with repeated measures (Picture Type [chocolate, object], Response Direction [push, pull], and Response Device [joystick, mouse, touchscreen]) were conducted. All main effects and interactions relevant for the main hypothesis are reported for initial RTs in the main manuscript. As results for final RTs resemble those of initial RTs, results are presented in the Supplementary Material.

As the between-subject factor Block Order influenced whether an approach bias was present, a multiple regression was run with block order, approach bias and their interaction as predictors and BMI, trait and state craving as well as ad libitum chocolate consumption as dependent variables. As we preregistered to run correlations between approach bias and different characteristics of chocolate eating behavior (BMI, trait and state craving, ad libitum chocolate consumption), these data will be presented in the Supplementary Material (Table S4). To obtain bias scores, differences between push and pull median RTs for each picture

type were calculated (i.e., $RT_{\text{push chocolate}} - RT_{\text{pull chocolate}}$). Then, object bias scores were subtracted from chocolate bias scores (double difference score) with higher values indicating a relative approach bias for chocolate-related pictures. To verify that chocolate-related pictures were rated as more pleasant than object-related pictures paired sample *t*-tests were performed.

Split-half reliability of the different tasks was analyzed using the AATtools package (Kahveci, 2019) for R (R Core Team, 2018). To compute the bootstrapped split-half reliability of each AAT response device, outliers were removed as reported above, after which the dataset of each AAT was randomly split in two balanced groups with equal or near-equal trials in each category (pull-food, push-objects, etc). Next, an approach bias score for each participant was computed from each half, using the median double-difference score (i.e., $\text{bias score}_{\text{chocolate}} - \text{bias score}_{\text{object}}$). Then, the correlation between approach bias scores for both halves was computed. This process was repeated 10,000 times, after which the average split-half reliability was computed, as well as 95% confidence intervals. Additionally, Spearman-Brown-corrected reliability scores are reported to account for the fact that bias scores were computed from halved datasets.

3. Results

3.1 Sociodemographic and anthropometric information

The final sample comprised 45 participants (67% female, $n = 30$) with a mean age of 28.64 years ($SD = 6.61$, range: 18-40) and a mean BMI of 24.40 kg/m^2 ($SD = 5.42$, range: 18.59 – 45.71). The majority of the sample was right-handed (98%, $n = 44$) and highly educated (60% high school graduation, $n = 27$). The mean daily chocolate consumption within the last week was 48.80g ($SD = 38.07$, range: 13.43 – 190.17). Twenty-four percent of participants ($n = 11$) indicated that they restricted their food intake. Questionnaire data is reported in Table 1.

Table 1. Chocolate Eating Behavior and Food-Related Variables.

| Measure | Mean (<i>SD</i>) | Range |
|---|--------------------|---------------|
| DEBQ total | 2.81 (0.51) | 1.80 – 3.73 |
| External eating | 3.40 (0.69) | 2.10 – 4.90 |
| Emotional eating | 2.67 (0.79) | 1.10 – 4.20 |
| Restrained eating | 2.35 (0.70) | 1.00 – 3.80 |
| PSRS | 12.76 (3.72) | 5.00 – 21.00 |
| Slim item #1 ("How important is it for you to monitor your weight?") | 4.31 (1.61) | 1.00 – 7.00 |
| Slim item #2 ("How important is it for you to be slim?") | 4.67 (1.52) | 1.00 – 7.00 |
| FCQ trait, t0 (chocolate version) | 42.40 (13.40) | 15.00 – 78.00 |
| FCQ state, t0 (chocolate version) | 39.73 (10.35) | 15.00 – 73.00 |
| FCQ state, t3 (chocolate version) | 42.71 (12.18) | 15.00 – 73.00 |
| Consumption taste test | 41.49 (19.63) | 12.19 – 95.37 |

Note. DEBQ = Dutch Eating Behavior Questionnaire. PSRS = Perceived Success in the Self-Regulation of Dieting Scale. FCQ = Food Cravings Questionnaire.

3.2 AAT error rates

After exclusion of participants with an excessive number of errors (i.e., >35% error 1 in any condition of any task), error 1 rates were 6% in the joystick AAT, 6% in the mouse AAT, and 11% in the touchscreen AAT, $F(2, 88) = 24.53, p < .001, \eta^2_p = .358$. Error 1 rates were significantly higher in the touchscreen AAT compared to the joystick and mouse AAT, $ps < .001$. Error 2 rates also differed significantly between response devices, $F(1.73, 77.14) = 4.98, p = .012, \eta^2_p = .102$ (joystick: 1.4%; mouse: 1.9%; touchscreen: 1.4%). Posthoc tests showed that error 2 rates were significantly higher in the mouse compared to the touchscreen AAT, $p = .006$ (all other comparisons, $ps > .08$).

3.3 Valence ratings, palatability ratings, and craving

As expected, chocolate-related pictures were rated as more pleasant compared to object-related pictures (food: $M = 71.51, SD = 15.21$; object: $M = 40.03, SD = 13.29$), $t(44) = 9.57, p$

< .001. Mean ratings of palatability and craving were $M = 68.82$, $SD = 16.06$, and $M = 58.98$, $SD = 20.73$, respectively.

3.4 Reaction times

Initial RT. Significant main effects of Picture Type, $F(1, 44) = 44.46$, $p < .001$, $\eta^2_p = .503$, and Response Direction, $F(1, 44) = 9.04$, $p = .004$, $\eta^2_p = .170$, emerged that were modulated by a significant two-way interaction of Picture Type x Response Direction, $F(1, 44) = 18.71$, $p < .001$, $\eta^2_p = .298$. As can be derived from Figure 2, across AAT tasks participants were faster to pull ($M = 578.95$; $SD = 41.96$) than to push chocolate-related pictures ($M = 607.59$; $SD = 52.13$), $t(44) = |4.87|$, $p < .001$, $d_z = 0.73$, whereas pull RTs were slower than push RTs for object-related pictures (Pull: $M = 622.17$; $SD = 59.01$; Push: $M = 609.21$; $SD = 49.08$), $t(44) = 2.58$, $p = .013$, $d_z = 0.38$. The main effect of Response Device was also significant, $F(2, 88) = 14.49$, $p < .001$, $\eta^2_p = .248$; but did not modulate the significant interaction of Picture Type x Response Direction, $F(1.58, 69.45) = 0.37$, $p = .644$, $\eta^2_p = .008$ (see Figure 2).

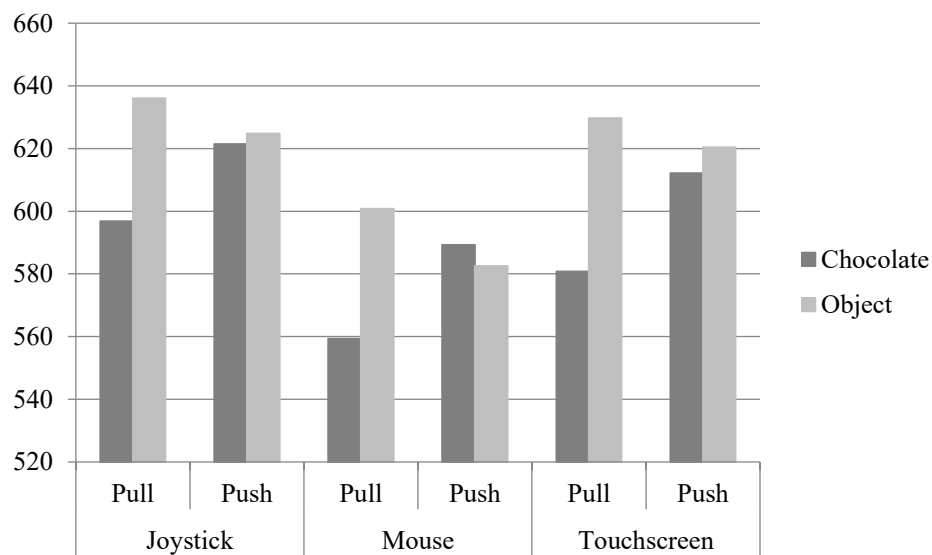


Figure 2. Initial RTs for Picture Type x Response Direction x Response Device: Means and Standard Errors.

3.5 Exploratory analyses

Exploratory analyses (also see Supplementary Material) showed that the 3-way interaction of Picture Type x Response Direction x Block Order was significant, $F(1, 27) = 6.31, p = .018, \eta^2_p = .189$ (see Figure 3). Post-hoc analyses within each block-order revealed that only participants who first received the incongruent instruction showed an approach bias; interaction Picture Type x Response Direction, $F(1, 23) = 48.24, p < .001, \eta^2_p = .677$. The interaction was not significant in participants who were instructed to pull chocolate-related pictures first, $F(1, 20) = 1.12, p = .302, \eta^2_p = .053$.

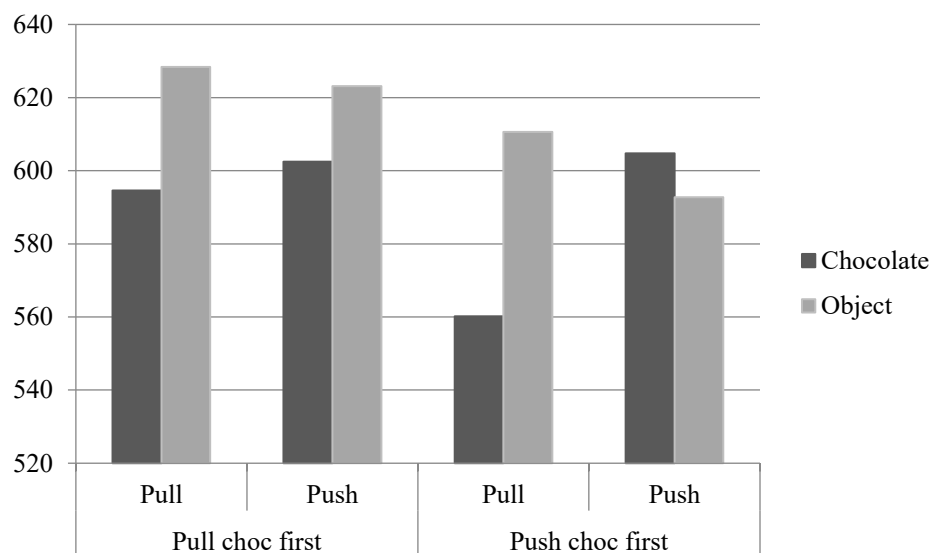


Figure 3. Interaction of Picture Type x Response Direction x Block Order: Means and Standard Errors.

3.6 Validity

On the other hand, we sought to quantify the relationship between approach bias scores for the three different response devices, and BMI, chocolate consumption, and trait and state food craving. We deviated from our pre-registration, because block order affected whether an approach bias was present, and thus hypothesized that block order likely influences task validity as well. Complementary to correlations (see Supplementary Material Table S4), we used linear regressions on the double difference scores to predict BMI, chocolate

consumption, FCQ-T score, as well as pre-test and post-test scores on the full FCQ-S scale and its craving subscale. We followed up each linear regression with a moderation analysis using approach bias, block order, and their interaction to predict the other variables.

Except for BMI ($t = -2.52, p = .16, \Delta R^2 = .13$), there were no unmoderated relationships between approach bias scores and any of the other variables, all $ps > .1$ (for detailed results see Supplementary Material Table S5). However, for the joystick-AAT only, the relationship of approach bias with state and trait craving was moderated by block order (see Table 2). Follow-up simple-slope analyses (see Table 3) confirmed that approach bias only had a positive linear association with state craving when participants received incongruent task instructions during the first block (thus, in the sequence where a clear bias was present).

Table 2. Moderation Analyses Predicting Chocolate Consumption, Trait Craving, State Craving, and BMI with Bias Score Moderated by Block Order (step 2).

| Predictor | DV | Joystick | | | Mouse | | | Touch | | |
|------------|------------------------|-------------|-------------|--------------|----------|----------|--------------|----------|----------|--------------|
| | | <i>t</i> | <i>p</i> | ΔR^2 | <i>t</i> | <i>p</i> | ΔR^2 | <i>t</i> | <i>p</i> | ΔR^2 |
| AB x Order | BMI | -1.33 | .191 | .17 | -0.61 | .545 | .04 | 0.62 | .541 | .06 |
| AB x Order | Consumption | -0.67 | .505 | .04 | -1.28 | .209 | .12 | 0.15 | .885 | .06 |
| AB x Order | FCQ-T | 2.35 | .024 | .14 | -0.77 | .447 | .03 | 0.79 | .435 | .04 |
| AB x Order | FCQ-S Pretest | 2.38 | .022 | .13 | 0.39 | .702 | .02 | 1.17 | .247 | .04 |
| AB x Order | FCQ-S-craving Pretest | 2.79 | .008 | .17 | 0.18 | .855 | .01 | 1.21 | .232 | .04 |
| AB x Order | FCQ-S Posttest | 3.10 | .004 | .24 | -0.18 | .861 | .07 | 0.1 | .918 | .02 |
| AB x Order | FCQ-S-craving Posttest | 3.43 | .001 | .27 | -0.33 | .747 | .07 | 0.21 | .833 | .02 |

Note. AB = approach bias. DV = dependent variable. BMI = Body Mass Index. FCQ-T = Food Cravings Questionnaire- Trait. FCQ-S = Food Cravings Questionnaire-State.

^a Item of the FCQ-S specifically referring to craving.

Table 3. Follow-up Analyses Predicting Questionnaire Scores Using Joystick AAT Bias Scores for Each Block Order.

| DV | Congruent-first | | | Incongruent-first | | |
|------------------------|-----------------|----------|-----------------------|-------------------|-------------|-----------------------|
| | <i>t</i> | <i>p</i> | <i>R</i> ² | <i>t</i> | <i>p</i> | <i>R</i> ² |
| FCQ-T | -1.93 | .069 | .16 | 1.46 | .158 | .09 |
| FCQ-S Pretest | -1.29 | .213 | .08 | 2.09 | .048 | .17 |
| FCQ-S-craving Pretest | -1.37 | .187 | .09 | 2.56 | .018 | .23 |
| FCQ-S Posttest | -0.96 | .349 | .05 | 3.52 | .002 | .36 |
| FCQ-S-craving Posttest | -1.05 | .308 | .05 | 3.89 | .001 | .41 |

Note. DV = dependent variable. FCQ-T = Food Cravings Questionnaire- Trait. FCQ-S = Food Cravings Questionnaire-State.

3.7 Reliability

We found moderate-to-good internal consistency (defined as split-half reliability scores) for the different response devices: joystick, $r = .62$, 95%CI = [.48, .75], $r_{SB} = .76$; mouse task, $r = .60$, 95%CI = [.44, .73], $r_{SB} = .75$; and touchscreen task, $r = .50$, 95%CI = [.31, .66], $r_{SB} = .67$.

4. Discussion

The aim of the present study was to test the hypothesis that individuals with regular chocolate consumption would show approach biases for chocolate-related pictures. Approach biases were assessed using three different AAT response devices (joystick AAT, mouse AAT, touchscreen AAT). Additionally, the psychometric properties (reliability, validity) of the three response devices were investigated using a within-subject design. At first glance, our first hypothesis was supported as participants reacted differently towards chocolate- and object-related pictures. More specifically, our pre-registered analysis revealed that chocolate-related pictures were pulled faster than pushed while the opposite pattern emerged for object-related pictures, indicating an approach bias for chocolate. The pattern of findings was similar across the different AAT response devices. However, exploratory analyses revealed that block order (congruent [pull chocolate first] vs. incongruent [push chocolate first]) affected bias scores. More specifically, an approach bias for chocolate-related pictures was clearly found when individuals received the incongruent instruction in the first and the congruent instruction in the second block of trials. No clear bias was evident in the congruent first condition. The

finding that block order affected bias scores must be regarded preliminary as analyses were exploratory and power (see limitations) for the moderation analyses low. Therefore, results need to be replicated in larger samples before firm conclusions can be drawn. If approach biases are more robust with incongruent task instructions presented first, this would be an important finding as previous findings were not that clear as biases were either weak (toward chocolate images, Meule, Richard, et al., 2019) related to low calorie foods (Maas et al., 2015), related to high calorie foods, but only emerged in specific subgroups (e.g., trait food cravers; study 3 in Becker et al., 2015; Brockmeyer et al., 2015), or absent (studies 1 and 2 in Becker et al., 2015). Learning/habituation effects on the bias should be traced across multiple instruction blocks to understand the mechanisms here, as task learning and biases likely interact dynamically over time. Our inclusion criterion concerning chocolate consumption might have resulted in us mostly testing high or moderately high chocolate food cravers.

As to the validity of the task, results of the planned analyses suggest that the AAT is not a valid measure as approach bias scores did not correlate with craving and ad-libitum chocolate consumption. As to the association between approach biases and chocolate-related variables, inconsistent (Lender et al., 2018) and null findings (Lender et al., 2018; Meule, Lender, et al., 2019; Meule, Richard, et al., 2019) have also been reported in previous studies. The findings that approach biases are not related to eating behavior could indicate that approach biases are not a relevant characteristic of (disturbed) eating behavior. However, in light of the assumptions of dual-process models and empirical findings, it seems more likely that approach biases predict eating behavior only under *certain conditions*: Automatic processes should predict eating behavior in situations in which a person does not have the opportunity and/or motivation to control them (Friedrich et al., 2008). Furthermore, experience sampling studies have provided evidence that although desires occur frequently in daily life, their enactment depends on a number of factors (e.g., self-control, personality traits, location, presence of other people, Hofmann et al., 2012). It has also been shown that positive implicit

evaluations are only associated with chocolate consumption if both hunger and craving are high (Richard et al., 2019). Therefore, in order to better understand under which circumstances approach biases predict eating behavior, they should be examined across a range of settings in everyday life, for example, by means of a mobile AAT (Zech et al., 2020).

As block order significantly affected bias scores in the present study, exploratory regression analyses were run, again showing that approach biases did not predict any of the variables relating to chocolate eating behavior (craving, BMI, ad-libitum chocolate consumption). As block order influenced whether a bias was present, a moderation analysis was run taking block order into account. This analysis revealed that except for BMI, there were no unmoderated associations. Follow-up analyses further revealed that only for the joystick AAT there was a positive association between craving scores and approach bias (but no association with eating-related variables) for participants who received the incongruent instruction first. These findings are in line with previous studies that found associations between approach biases and state craving (e.g., Lender et al., 2018) and no association with eating-related variables (Meule, Richard, et al., 2019). Kahveci et al. (2020) also found a relationship between a robust food bias and individual food preferences. These state-related findings are in line with the assumptions of the Incentive-Sensitization-Theory (Robinson & Berridge, 1993, 2008) that approach biases are related to motivational states of ‘wanting’. Surprisingly, although approach biases were present in all AAT tasks, the significant associations were only found for the joystick AAT such that approach biases predicted state craving when participants received the incongruent instruction first. If replicated, results suggest that the joystick AAT with explicit and incongruent instructions in the first block is the most valid task to assess behavioral tendencies. To address block order effects, a higher number of instruction switches could be used to ‘spread’ the learning process more evenly across the task time line. A recent study with six instruction blocks (five switches of instructions) revealed robust biases, but no order effects (van Alebeek et al., in revision).

Results need to be interpreted against the background of several limitations. Although we conducted an a-priori power analysis, the final sample size was relatively small, reducing statistical power, particularly for the exploratory analyses. A post-hoc power analysis with the final sample size of 45 participants analysis revealed that power was .72 (repeated measures design, $f = .175$, $\alpha = .05$, $\beta = .80$). Regarding the power of the correlational/regression analyses, with a sample size of 45 participants the power to detect a medium correlation effect ($r = .30$) is .56. We ran 10000 moderation analyses with simulated data to estimate how much power there is to demonstrate an effect for the moderation analyses. Given a medium interaction effect in the data (coefficient $\beta = .35$ according to Acock [2014]), power is .20, and given a very strong interaction effect (coefficient $\beta = 1$), power is .86. Therefore, given the low power of the study, replication in larger samples is needed.

We did not check objectively (e.g., bogus blood sugar tests) whether participants complied with the instruction of not eating two hours prior to study participation. Therefore, we cannot verify how successful the instruction was. Generalizability of findings is restricted by the selected sample (highly educated participants, mostly high trait food craving, higher on restrained eating compared to the general population [Nagl et al., 2016], restricted age range) and the focus on chocolate as stimulus content. Therefore, results need to be replicated in other samples and with different stimuli before firm conclusions can be drawn. Additionally, stimuli were pre-selected although it is conceivable that approach biases are stronger for idiosyncratic attractive food (e.g., Kahveci et al., 2020; Meule, Lender, et al., 2019), therefore, it would be interesting to assess biases for individually selected stimuli in future studies.

In conclusion, results of the present study showed that approach biases for chocolate can be investigated with all three AAT response devices. Block order affected results and this effect needs to be solved in future studies. Overall, the validity of the AAT response devices remains inconclusive; split-half reliability of all AATs ranged between $r_{SB} = .67$ -.76. Results

need to be replicated in larger and with different samples before firm conclusions can be drawn.

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Author Contributions

Study design: CEW, SK (Hamburg), JB, AL

Data acquisition: TS

Data analysis: CEW, SK (Salzburg)

Writing of manuscript: CEW

Revision of manuscript: SK (Hamburg & Salzburg), JB, TS, AL

Conflict of Interest

Charlotte E. Wittekind, Tanja Schiebel, Anja Lender, Sercan Kahveci: None.

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Figures

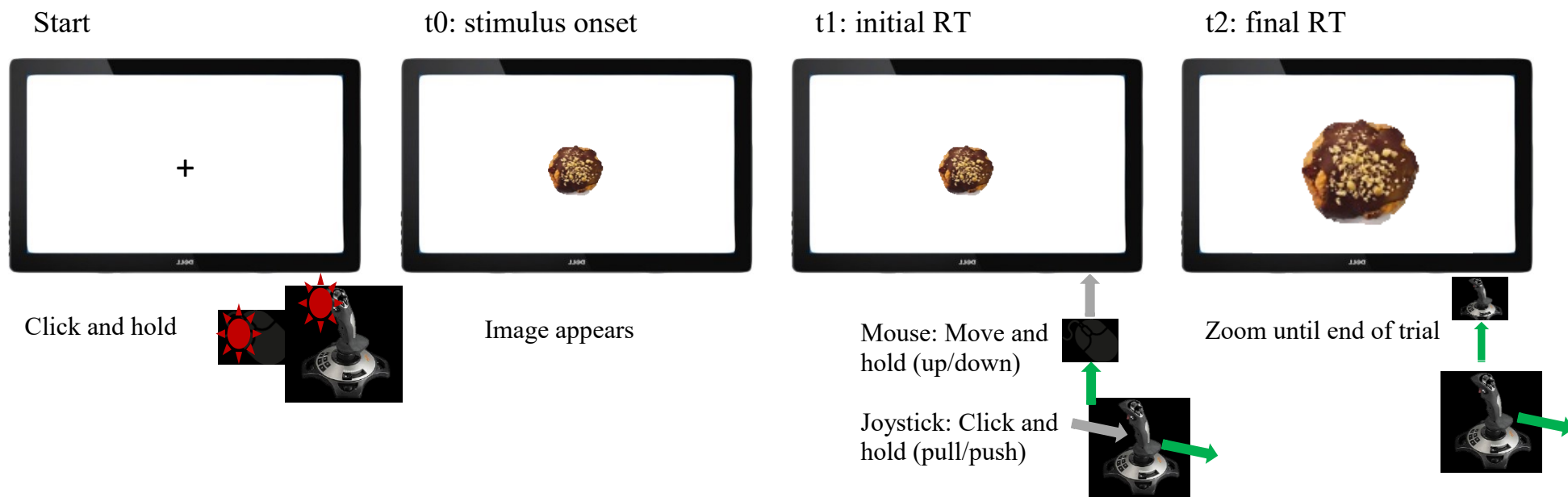


Figure 1a. Example trial of the mouse/joystick AAT with congruent instructions (i.e., pull chocolate, push objects). When the mouse/joystick is pulled, the picture size increases, when the mouse/joystick is pushed, the pictures decreases in size.

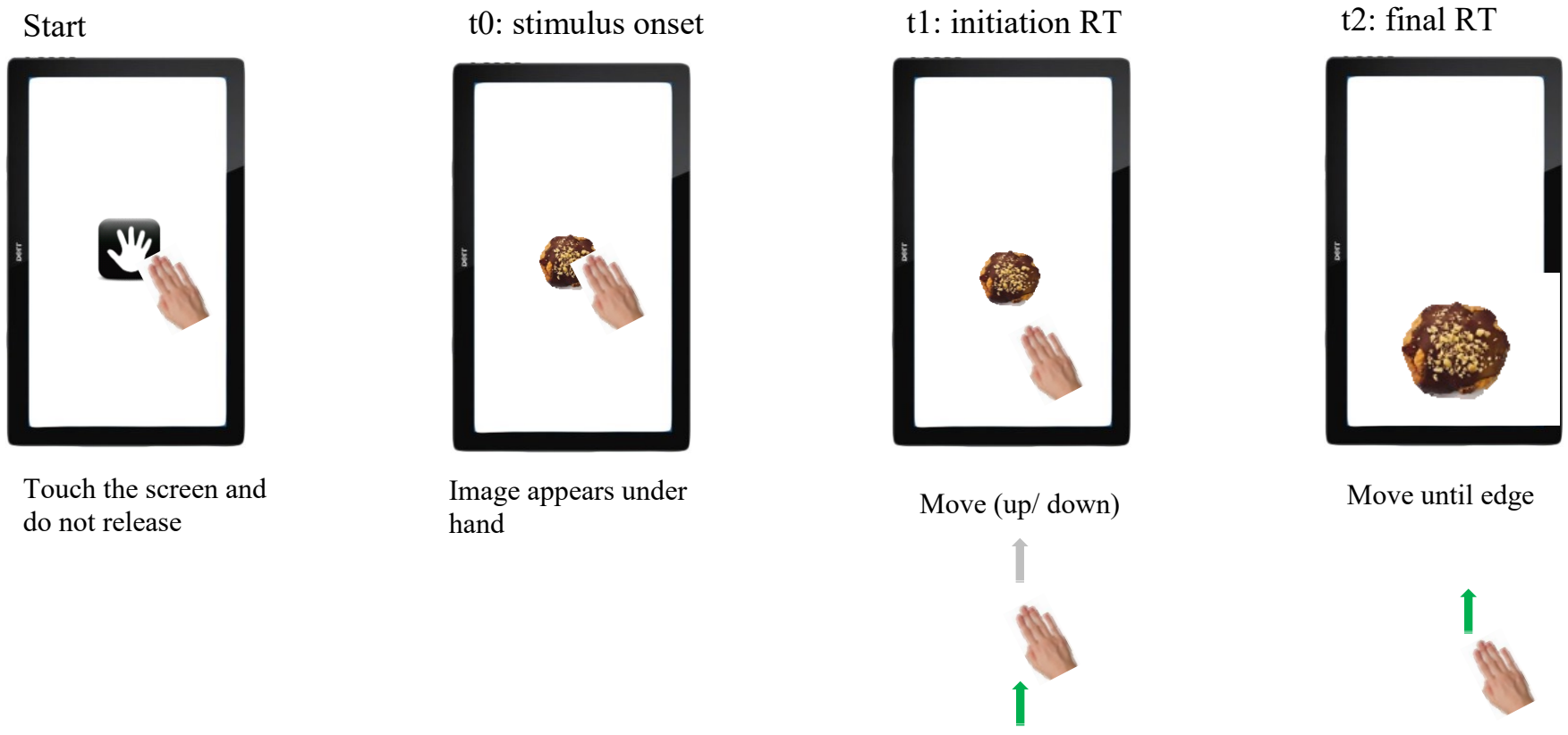


Figure 1b. Example trial of the touchscreen AAT with congruent instructions (i.e., pull chocolate, push objects). When the hand swipes to the bottom of the screen, picture size increases, when the picture is swiped to the top picture size decreases.

Appendix A. Supplementary Material

Comparison of different response devices to assess behavioral tendencies towards chocolate
in the Approach-Avoidance Task

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Material*Stimulus selection***Table S1.** Numbers of pictures of each picture set.

| | Set 1 | Set 2 | Set 3 |
|-----------|-------|-------|-------|
| Chocolate | 0004 | 0101 | 0083 |
| | 0048 | 0137 | 0097 |
| | 0107 | 0139 | 0127 |
| | 0111 | 0163 | 0134 |
| | 0159 | 0165 | 0160 |
| | 0169 | 0173 | 0167 |
| | 0344 | 0286 | 0170 |
| | 0465 | 0287 | 0289 |
| | 0499 | 0291 | 0293 |
| | 0510 | 0298 | 0441 |
| Objects | 1015 | 1004 | 1010 |
| | 1018 | 1028 | 1047 |
| | 1038 | 1035 | 1049 |
| | 1045 | 1095 | 1056 |
| | 1055 | 1139 | 1129 |
| | 1060 | 1146 | 1140 |
| | 1130 | 1188 | 1187 |
| | 1241 | 1212 | 1235 |
| | 1265 | 1236 | 1246 |
| | 1270 | 1279 | 1250 |

Examples of object-related pictures:



*Counterbalancing***Table S2.** Counterbalancing of AATs, Stimulus Sets, and Block Order.

| Participant | Order of AATs | Order of Stimulus Sets | Block Order |
|-------------|------------------------------|------------------------|-------------|
| 1 | Touchscreen, mouse, joystick | 0, 1, 2 | pull, push |
| 2 | Mouse, joystick, touchscreen | 1, 2, 0 | push, pull |
| 3 | Joystick, touchscreen, mouse | 2, 0, 1 | pull, push |
| 4 | Touchscreen, mouse, joystick | 1, 2, 0 | push, pull |
| 5 | Mouse, joystick, touchscreen | 2, 0, 1 | pull, push |
| 6 | Joystick, touchscreen, mouse | 0, 1, 2 | push, pull |
| 7 | Touchscreen, mouse, joystick | 2, 0, 1 | pull, push |
| 8 | Mouse, joystick, touchscreen | 0, 1, 2 | push, pull |
| 9 | Joystick, touchscreen, mouse | 1, 2, 0 | pull, push |

Note. After nine participants the depicted sequence was repeated.

Results

Error rates

Table S2. Error rates (%) per condition, response direction, and task for the whole sample ($N = 54$).

| | Chocolate | | Object | |
|----------|-----------|------|--------|------|
| | Push | Pull | Push | Pull |
| Joystick | 8% | 4% | 9% | 7% |
| Mouse | 6% | 5% | 6% | 9% |
| Touch | 11% | 10% | 14% | 17% |

Initial RT: Influence of Block Order, Order of Stimulus Set, and Order of Response Device

The 6-way ANOVA with Order of Stimulus Set, Order of Response Device, and Block Order as between-subject factors and Picture Type, Response Direction, and Response Device as within-subject factors revealed that the 2-way interaction of Picture Type x Response Direction was qualified by Block Order, $F(1, 27) = 6.31, p = .018, \eta^2_p = .189$. The two-way interaction of Picture Type x Response Direction was neither influenced by the Order of Response Device, $F(2, 27) = 1.58, p = .225, \eta^2_p = .105$, nor by the Order of Picture Sets, $F(2, 27) = 3.09, p = .062, \eta^2_p = .186$. The 3-way interaction Picture Type x Response Direction x Response Device was neither influenced by Block Order, Order of Picture Sets, or Order of Response Device, all $ps > .1$.

Final RT: Influence of Block Order, Order of Stimulus Set, and Order of Response Device

As for initial RTs the 6-way ANOVA with Order of Stimulus Set, Order of Response Device, and Block Order as between-subject factors and Picture Type, Response Direction, and Response Device as within-subject showed that the 2-way interaction of Picture Type x Response Direction was influenced by Block Order, $F(1, 27) = 7.40, p = .011, \eta^2_p = .215$, but not by Order of Picture Sets and Order of Response Device, $ps > .1$. Again, post-hoc analyses elucidated that the 2-way interaction was not significant for participants who received the

congruent instruction first (i.e., pull chocolate), $F(1, 20) = 0.90, p = .904, \eta^2_p = .001$, but only for participants receiving the incongruent instruction first, $F(1, 23) = 26.53, p < .001, \eta^2_p = .536$. Resembling findings for initial RTs, the 3-way interaction Picture Type x Response Direction x Response Device was neither influenced by Block Order, Order of Picture Sets nor Order of Response Device, all $ps > .5$.

Final RT: Results for the interactions Picture Type x Response Direction and Picture Type x Response Direction x Response Device.

The pattern of findings resembles those of initial RTs (see Figure S1). The significant main effects of Picture Type, $F(1, 44) = 30.56, p < .001, \eta^2_p = .410$, and Response Direction, $F(1, 44) = 14.60, p < .001, \eta^2_p = .249$, were qualified by the significant interaction of Picture Type x Response Direction, $F(1, 44) = 7.05, p = .011, \eta^2_p = .138$. Although the main effect of Response Device was significant, $F(2, 88) = 70.13, p < .001, \eta^2_p = .614$, it did not moderate the 2-way interaction, $F(2, 88) = 0.34, p = .711, \eta^2_p = .008$.

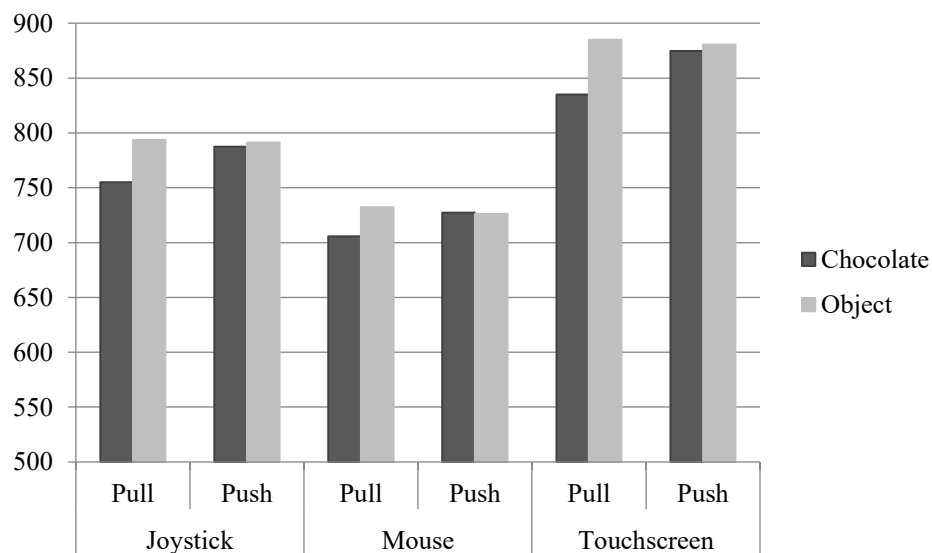


Figure S1. Final RTs for Picture Type x Response Direction x Response Device: means and standard errors.

The significant interaction was followed-up by comparing pull and push RTs for chocolate- and object-related pictures separately. Pull RTs were significantly faster than push RTs for chocolate-related pictures (Pull: $M = 765.27$, $SD = 76.45$; Push: $M = 796.42$, $SD = 88.98$), $t(44) = |3.67|$, $p = .001$. No RT differences for pull and push movements were found for object-related pictures (Pull: $M = 803.54$, $SD = 90.80$; Push: $M = 799.29$, $SD = 85.76$), $t(44) = |0.66|$, $p = .513$

Correlations

As specified in the pre-registration, correlations between approach bias scores (double difference score) and BMI, state and trait craving, as well as ad libitum chocolate consumption were performed. As BMI was not normally distributed, Spearman rho is reported (see Table S4).

Table S4. Correlations Between AAT Tasks, BMI, Craving, and Ad-Libitum Chocolate Consumption.

| | Approach bias joystick | Approach bias mouse | Approach bias touch | State Craving | Trait Craving | Food consumption | BMI |
|------------------------|------------------------|---------------------|---------------------|---------------|---------------|------------------|-----|
| Approach bias joystick | 1 | | | | | | |
| Approach bias mouse | .161 | 1 | | | | | |
| Approach bias touch | .481** | .515** | 1 | | | | |
| State Craving | -.002 | .068 | -.071 | 1 | | | |
| Trait Craving | -.101 | -.081 | -.133 | .558** | 1 | | |
| Food consumption | -.145 | .234 | .212 | .243 | .212 | 1 | |
| BMI | -.339* | -.085 | -.234 | -.247 | -.001 | .367* | 1 |

Note. BMI = Body Mass Index.

* $p < .05$; ** $p < .01$.

Validity

Table S5. Moderation Analyses Predicting Chocolate Consumption, Trait Craving, State Craving, and BMI with Predictors for Bias Scores (step 1).

| Predictor | DV | Joystick | | | Mouse | | | Touch | | |
|-----------|--|--------------|-------------|--------------|----------|----------|--------------|----------|----------|--------------|
| | | <i>t</i> | <i>p</i> | ΔR^2 | <i>t</i> | <i>p</i> | ΔR^2 | <i>t</i> | <i>p</i> | ΔR^2 |
| AB | BMI | -2.52 | .016 | .13 | -1.02 | .312 | .02 | -1.29 | .204 | .04 |
| AB | Consumption | -0.98 | .331 | .02 | 1.52 | .136 | .05 | 1.23 | .225 | .03 |
| AB | FCQ-T | -0.66 | .514 | .01 | -0.55 | .584 | .01 | -0.81 | .422 | .02 |
| AB | FCQ-S Pretest | 0.04 | .972 | 0 | 0.41 | .686 | 0 | -0.36 | .723 | 0 |
| AB | FCQ-S-craving Pretest | 0.3 | .765 | 0 | 0.19 | .852 | 0 | -0.17 | .869 | 0 |
| AB | FCQ-S Posttest | 0.81 | .423 | .01 | 1.34 | .187 | .04 | -0.41 | .682 | 0 |
| AB | FCQ-S-craving ^a Posttest | 0.89 | .376 | .02 | 1.14 | .26 | .03 | -0.3 | .767 | 0 |

Note. AB = approach bias. DV = dependent variable. BMI = Body Mass Index. FCQ-T = Food Cravings Questionnaire- Trait. FCQ-S = Food Cravings Questionnaire-State.

^a Item of the FCQ-S specifically referring to craving.