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Imaginal retraining reduces craving for high-calorie food

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A B S T R A C T

Imaginal retraining (IR) is a treatment derived from approach bias modification to reduce strong craving for high-calorie food. The push component (IR_{push}) seems to be the most effective element according to a recent dismantling trial. Conclusions derived from prior studies are limited, however, by small sample sizes and restriction of participants to women. The present study aimed to overcome these limitations and also tested a new variant of IR (3P; decoupling with the elements *pull, pause, push*), which has previously been found to be more effective than the standard protocol in individuals with problematic alcohol use.

The study was conducted online. A total of 1,106 participants with strong craving for high-calorie food were randomized to different brief interventions of IR or a passive control group. Before and after the interventions, participants indicated their craving for high-calorie food and appraised food pictures. The main conditions of interest were IR_{push} and 3P. The other two experimental conditions did not contain a motor element and served as active control conditions.

IR_{push} proved the most effective intervention and reduced craving by approximately 18%, which was significantly larger than in the passive control group. IR_{push} worked especially well for those with higher initial weight, higher cravings, and more dysfunctional eating behavior. The novel 3P technique significantly reduced craving across time and was especially effective for those with high BMI and craving.

The study suggests that a simple self-help component of imaginal retraining, IR_{push}, can decrease craving for high-calorie food to a relevant extent. Future trials should elucidate whether different forms of substance-related and behavioral addictions require adapted IR or 3P protocols to increase effectiveness.

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1. Introduction

Craving high-calorie food is implicated in overeating and obesity (Reents & Pedersen, 2021; Verzijl, Ahlich, Schlauch, & Rancourt, 2018), which in turn represent major causes of various debilitating somatic disorders such as diabetes (La Sala & Pontiroli, 2020), high blood pressure (Chrysant, 2019; Cohen, 2017), and chronic kidney disease (Whaley-Connell & Sowers, 2017). In addition, obesity is a contributing factor in psychological disorders such as anxiety and depression (Amiri & Behnezhad, 2019; Rajan & Menon, 2017; Rao et al., 2020) as well as ostracism and (self-)stigma (Albano, Rowlands, Baciadonna, Coco, & Cardi, 2019; Alimoradi et al., 2020; Puhl & Suh, 2015). Thus, craving high-calorie food should be considered a key treatment target as its reduction contributes to somatic and mental health in multiple ways (Koliaki, Liatis, & Kokkinos, 2019; Rajan & Menon, 2017).

Apart from more invasive pharmacological (Rebello et al., 2018; Rebello & Greenway, 2016) and surgical interventions (Koball, Ames, Goetze, & Grothe, 2020), behavioral strategies such as stimulus control (Wolz, Nannt, & Svaldi, 2020) have been adopted to reduce craving for high-calorie food. Approach bias modification (ABM), a novel treatment approach for substance-related and behavioral addictions, acts on implicit cognitions via embodiment. Studies using ABM demonstrate that moving a joystick away from oneself when sitting in front of a computer screen if an unhealthy food/substance is shown and moving it towards oneself if a picture of a healthy food/substance is shown improves health-related outcomes (Kakoschke, Kemps, & Tiggemann, 2017a; Schumacher, Kemps, & Tiggemann, 2016; Yang et al., 2019). Yet, the effects are small, and not all clinical studies have been able to confirm the efficacy of the intervention (Jones, Hardman, Lawrence, & Field, 2018; Kakoschke, Kemps, & Tiggemann, 2017b). To augment the

efficacy and generalizability of the approach, we adapted the computerized ABM procedure to the imagination (i.e., the craved substance has to be imagined and is not displayed anymore via photos), thus allowing greater personalization (Moritz, Gehlenborg, Wirtz, Ascone, & Kühn, 2021; Moritz, Göritz, et al., 2019; Moritz, Paulus, et al., 2019; Wirtz, Ascone, Gehlenborg, Moritz, & Kühn, 2021). This so-called imaginal retraining (IR) approach has been found effective in reducing craving for substances in the short term (Moritz, Paulus, et al., 2019, 2020; Moritz, Paulus, et al., 2019) and in the long term (Gehlenborg, Göritz, Moritz, Lüdtke, & Kühn, 2022). In IR, participants are instructed to imagine their desired substance after engaging in a negative mood induction. Individuals are then asked to imagine throwing the substance away from themselves (e.g., throwing a piece of cake against a wall) while actually performing the movement. Participants alternate this with an exercise corresponding to the approach movement in the ABM procedure. When performing the approach movement, they should first engage in a positive mood induction before imagining consuming a healthy food in a somewhat exaggerated pose. The mood induction is intended to dampen (or augment) the emotions associated with unhealthy/healthy food, but this step may be dispensable, according to a recent study (Wirtz, Moritz, Gehlenborg, Ascone, & Kühn, 2022). In a study on 384 women with strong craving for high-calorie food (Moritz, Göritz, et al., 2019), we found that adopting IR, especially when assisted with electronic reminders to perform the exercises, led to a significant decline in craving as well as in improvement to several other eating-related outcomes relative to a control group at small to medium effect sizes. Those who performed the exercises on a regular basis (per protocol condition) lost approximately 3 kg in the condition with additional electronic reminders. This study was limited, however, by its testing women only and its use of a complex intervention protocol that did not allow distinguishing between core and dispensable mechanisms of the action. Hence, we subsequently conducted a dismantling study on 113 women with strong craving for high-calorie food (Wirtz et al., 2021), all of whom had participated in the prior trial. Participants were randomized to different components of the technique. We were especially interested in whether the motor component of the retraining (i.e., actually performing the push and pull movements with the arm) represents a necessary precondition of the effect, which would lend further support to the notion of embodiment (Fridland & Wiers, 2018). We detected a reduction in craving in the push component of the imaginal retraining condition (IR_{push}) and in the condition conducting the push exercise only in the imagination (i.e., without an actual arm movement; IR_{no}) at nonsignificant statistical trend level (see the methods section for a more detailed description of the techniques). When both conditions were pooled, reduction in craving was significant. In addition, participants' appraisal of pictures of high-calorie food was significantly reduced when both imaginal retraining conditions were combined, at medium to large effect sizes. Yet, the dismantling study was limited by low power. Moreover, the sample was again confined to women, limiting the generalizability of the findings.

Recently, we tested a new technique called 3P (named after the main treatment elements *pull, pause, push*; for the protocol of the 3P technique, see the methods section) representing a synthesis of IR_{push} and decoupling. Decoupling is a self-help intervention that has been successfully tested in body-focused repetitive behaviors (BFRBs) such as trichotillomania, nail-biting, and lip-cheek biting (Moritz, Fricke, Treszl, & Wittekind, 2012; Moritz, Göritz, et al., 2020; Moritz, Penney, Ahmed, & Schmotz, 2021). In decoupling (see also methods section), the participant initially performs the dysfunctional movement (nail biting: moving fingers to mouth; problematic alcohol use: raising drink to mouth). Closely before termination (e.g., biting, drinking) the participant throws away the hand to irritate and "over-write" the dysfunctional behavioral script. In a study on 227 individuals with problematic alcohol use, 3P was significantly more effective in reducing craving for alcohol than passive and active control conditions (Moritz, Göritz, & Gehlenborg, 2022). Numerically, it was also better than IR_{push} (34.5% vs. 14.8%) but the difference failed to achieve significance.

The present study aimed to fill some methodological gaps of the forerunner study and examined a large sample of both men and women with high craving for high-calorie food. Using a longitudinal pre-post design (analyses of variance for the pre-post differences followed by post-hoc single comparisons), we hypothesized that the augmented imaginal retraining technique (3P) would be more successful than the original technique in reducing craving for high-calorie food (Wirtz et al., 2022).

2. Method

The study was conducted online as a randomized controlled trial (RCT). Recruitment was carried out online via WisoPanel (Göritz, 2009), drawing on a pool of individuals from the general population who are registered for participation in web-based studies (appr. 14,000 registered members). We intended to recruit at least 200 participants per condition to allow for identification of small between-group effects. The final sample comprised 1,106 participants. Recruitment was terminated one week after having sent the invitation e-mail to potential participants. The trial was registered with the German Clinical Trials Register (DRKS00028199; ethical approval: LPEK-0440). The major inclusion criterion was the participants' self-reported wish to reduce their strong craving for high-calorie food. Self-reported craving for high-calorie food was the primary outcome.

At the end of the study, participants were rewarded for study participation through access to a smartphone app to enhance psychological well-being as well as to a video at www.uke.de/sucht (English version: www.uke.de/craving) showing the full imaginal retraining procedure.

2.1. Measures

Participants were asked to fill out the *Food Cravings Questionnaire-Trait-reduced (FCQ-T-R)* (Meule, Hermann, & Kübler, 2014). The FCQ-T- is correlated with the BMI as well as with impulsiveness and is negatively correlated with success in diets (Meule et al., 2014). The short form consists of five subscales: lack of control over eating (Lack of Control), thoughts or preoccupation with food (Thoughts/Preoccupation with Food), intentions and plans to consume food (Intentions to Consume), emotions before or during food craving (Emotions), and cues that may trigger food craving (Triggers). Internal consistency (α = 0.94) as well as test–retest reliability (r = 0.74) have been found to be good (Meule et al., 2014; Pudel & Westhöfer, 1989). Higher scores indicate more problematic eating behavior.

The German *Three-Factor Eating Questionnaire* (Fragebogen zum Essverhalten, FEV; Pudel & Westhöfer, 1989) is a multidimensional questionnaire that incorporates the English Three-Factor Eating Questionnaire (TEFQ; Stunkard & Messick, 1985). Its three subscales are Cognitive Restraint from Eating (e.g., "I consciously hold back at meals in order not to gain weight"), Disinhibition ("I usually eat too much at social occasions, like parties and picnics") and Hunger (e.g., "I am usually so hungry that I eat more than three times a day"). Good validity and internal consistency have been reported (Cronbach's α = 0.74–0.87) (Pudel & Westhöfer, 1989).

Next, participants rated their current level of craving for high-calorie food (primary outcome) on a visual analogue scale ranging from 0 (not at all) to 100 (extreme) via a slider that could be moved in steps of 10 scale points. Participants were also asked to rate three pictures showing high-calorie food on a similar slider with the endpoints 'repulsive' (= 0) and 'appealing' (= 100).

2.2. Experiment

After a filler scale (Patient Health Questionnaire 9, PHQ-9 scale, with

additional question; Kroenke, Spitzer, & Williams, 2001), participants were randomized to one out of five conditions. In each condition including the control condition, participants were shown the same photo depicting different high-calorie foods (i.e., snacks and fast food). Different written instructions were given for each condition: (1) in the passive control condition (C), participants were instructed to just look at the photo for some time; (2) in the zooming-out condition (Z), they were asked to close their eyes and make the photo smaller in their imagination; (3) in the imaginal retraining condition without movement (IR_{no}), participants were asked to imagine throwing the sweets/fast food displayed in the picture away from themselves with some contempt but without making an actual arm movement; (4) in the imaginal retraining condition with movement (IR_{push}), they had to do the same as in 3 but this time accompany their imagining with the actual movement; and (5) in the decoupling/3P condition (D), participants were told to imagine bringing the food displayed close to their mouth (pull phase), hold the food close to their mouth (for the length of time it would usually take them to take their first bite; pause phase), and then throw the food away from themselves while making the actual movement (push phase). In conditions 2–5, the exercises had to be performed at least five times in accordance with prior studies on imaginal retraining.

Next, participants indicated whether they had actually executed the task and again rated the three food pictures and indicated their current level of craving for high-calorie food on the visual analogue scale described before from 0 to 100. In total, participants were presented 7 photos (2 (pre, post) x 3 pictures showing high-calorie food that should be rated according to subjective appeal; another picture showing different high-calorie food was displayed along with the intervention; we provided no specific instructions whether participants should manipulate the different food items displayed on the picture sequentially or all at once, see appendix). Unlike announced in the trial protocol (DRKS00028199), we did not collect any long-term follow-up.

2.3. Strategy of data analysis

We conducted two types of analyses, an intention-to-treat analysis with all participants who had performed the exercises (N = 1,106) and a per protocol analysis with all participants who indicated that they had performed the instructions properly (n = 1,011). Due to the quasi-crosssectional character of the study (the intervention was brief and executed at one assessment point), no dropout/noncompletion occurred between pre and post intervention. We examined whether conditions were similar at baseline, which was the case (see Table 2) and investigated whether conditions differed across time on appraisal, and craving; Table 2 also reports within-group differences across time. We expected that 3P/decoupling and IR_{push} would be superior to the control group with 3P/decoupling showing largest improvements.

3. Results

As shown in Table 1, groups did not differ on any sociodemographic variable or psychometric scale except for the FEV Cognitive Restraint subscale (one out of 18 baseline parameters examined). If scores on this variable were entered as a covariate in subsequent analyses, results remained essentially unchanged. The participants were largely comprised of people in their early to mid-50s. The participants were slightly overweight, as defined by a body mass index (BMI) greater than or equal to 25 (fulfilled by 63.4% of the sample). The criterion for

Table 1
Sample characteristics across conditions.

	Control (C, $n = 233$)	Zooming Out (Z, $n = 200$)	Imaginal Retraining Movement (IR_{push}, $n = 215$)	Imaginal Retraining Without Movement (IR_{no}, $n = 230$)	Decoupling/3P (D, $n = 228$)	Statistics
Demographics						
Age [years]	53.46 (13.41)	53.46 (13.41)	54.75 (13.44)	52.80 (13.24)	53.12 (13.87)	$F(4,1101) = 1.37$, $p = .243$, $\eta_p^2 = .005$
Gender (women)	54.5%	61.5%	61.4%	61.7%	65.8%	$\chi^2(4) = 6.41$, $p = .170$
Height [cm]	172.77 (8.81)	171.87 (9.20)	172.42 (8.79)	171.63 (9.02)	170.59 (9.37)	$F(4,1097) = 1.96$, $p = .098$, $\eta_p^2 = .007$
Weight [kg]	82.12 (20.96)	82.63 (20.49)	82.20 (18.30)	82.62 (22.19)	83.34 (20.17)	$F(4,1097) = 0.13$, $p = .973$, $\eta_p^2 < .001$
BMI	27.42 (6.12)	27.90 (6.52)	27.65 (5.89)	27.99 (7.07)	28.52 (6.02)	$F(4,1094) = 0.97$, $p = .424$, $\eta_p^2 = .004$
Scales						
FCQ-T-R						
Lack of Control	14.71 (5.20)	14.62 (5.15)	14.10 (5.56)	14.62 (5.42)	14.02 (5.23)	$F(4,1101) = 0.84$, $p = .501$, $\eta_p^2 = .003$
Thoughts/ Preoccupation with Food	10.90 (4.88)	11.01 (5.39)	10.93 (5.65)	11.46 (5.36)	10.82 (5.25)	$F(4,1101) = 0.52$, $p = .721$, $\eta_p^2 = .002$
Intentions to Consume	5.60 (2.17)	5.62 (2.26)	5.31 (2.27)	5.65 (2.28)	5.52 (2.28)	$F(4,1101) = 0.82$, $p = .514$, $\eta_p^2 = .003$
Emotions	5.60 (2.50)	5.43 (2.45)	5.33 (2.63)	5.57 (2.60)	5.54 (2.61)	$F(4,1101) = 0.43$, $p = .787$, $\eta_p^2 = .002$
Triggers	3.27 (1.14)	3.22 (1.22)	3.09 (1.24)	3.25 (1.25)	3.23 (1.24)	$F(4,1101) = 0.72$, $p = .575$, $\eta_p^2 = .003$
Total	40.08 (13.44)	39.89 (14.18)	38.76 (15.12)	40.54 (14.77)	39.14 (14.38)	$F(4,1101) = 0.56$, $p = .690$, $\eta_p^2 = .002$
FEV Cognitive Restraint	6.96 (4.27)	7.54 (4.47)	8.31 (4.60)	7.85 (4.58)	8.25 (4.63)	$F(4,1101) = 3.45$, $p = .008$, $\eta_p^2 = .012$; C < IR_{push}, IR_{no}, D; IR_{no} < IR_{push}
FEV Disinhibition	7.48 (3.90)	7.13 (3.94)	7.16 (4.12)	7.33 (3.97)	7.37 (3.97)	$F(4,1101) = 0.31$, $p = .872$, $\eta_p^2 = .001$
FEV Hunger	6.42 (3.51)	6.16 (3.83)	6.20 (3.66)	6.43 (3.63)	6.60 (3.57)	$F(4,1101) = 0.54$, $p = .708$, $\eta_p^2 = .002$
PHQ-9	6.95 (5.60)	6.47 (5.17)	6.97 (5.94)	6.57 (5.55)	6.99 (5.41)	$F(4,1101) = 0.44$, $p = .777$, $\eta_p^2 = .002$

Notes. BMI = body mass index; *FCQ-T-R = Food Cravings Questionnaire-Trait-reduced; FEV = Three-Factor Eating Questionnaire; PHQ-9 = Patient Health Questionnaire-9.*

Table 2
Changes across time in craving and food appraisal (analyses of variance). Paired sample *t*-test and improvement in percentage in square brackets.

	Control (C, n = 233)	Zooming Out (Z, n = 200)	Imaginal Retraining With Movement (IR_{push}, n = 215)	Imaginal Retraining Without Movement (IR_{no}, n = 230)	Decoupling/3P (D, n = 228)	Statistics
Intention to Treat						
Craving baseline	43.95 (27.16)	40.95 (28.19)	42.74 (27.81)	41.74 (26.33)	44.47 (27.00)	$F(4,1101) = 0.63$, $p = .638$, $\eta_p^2 = .002$
Change in craving (reduction)	1.85 (17.23) [4.21%, n.s., $d = 0.11$]	5.30 (18.59) [12.94%, ****, $d = 0.28$]	7.67 (21.36) [17.95%, ****, $d = 0.36$]	3.78 (21.76) [9.06%, **, $d = 0.17$]	5.22 (18.14) [11.74%, ****, $d = 0.29$]	$F(4,1101) = 2.71$, $p = .029$, $\eta_p^2 = .010$; C < IR_{push} ($p = .002$), D ($p = .063$), Z ($p = .066$)
Appraisal of food pictures	64.99 (17.48)	62.73 (16.52)	64.79 (18.31)	62.49 (17.10)	63.89 (16.58)	$F(4,1101) = 0.98$, $p = .416$, $\eta_p^2 = .004$
Change in appraisal of food pictures (less positive)	1.75 (10.06) [**, $d = 0.17$]	3.45 (8.19) [****, $d = 0.42$]	4.82 (8.41) [****, $d = 0.57$]	3.23 (9.65) [****, $d = 0.33$]	4.99 (10.05) [****, $d = 0.50$]	$F(4,1101) = 4.56$, $p = .001$, $\eta_p^2 = .016$; C < Z ($p = .059$), IR_{post} ($p = .001$), D ($p < .001$); Z < D ($p = .090$); IR_{no} < D ($p = .045$), IR_{post} ($p = .073$)
Per protocol						
Craving baseline (reduction)	44.20 (27.39)	39.94 (28.43)	43.11 (27.98)	41.32 (26.37)	44.69 (26.93)	$F(4,1000) = 1.03$, $p = .390$, $\eta_p^2 = .004$
Change in craving (reduction)	1.14 (17.06) [2.58%, n.s., $d = 0.07$]	5.62 (18.80) [14.07%, ****, $d = 0.30$]	8.08 (20.99) [18.74%, ****, $d = .038$]	3.25 (19.34) [7.87%, *, $d = 0.18$]	4.93 (18.34) [11.03%, ****, $d = 0.27$]	$F(4,1000) = 3.86$, $p = .004$, $\eta_p^2 = .015$; C < Z ($p = .019$), IR_{push} ($p < .001$), D ($p = .037$); IR_{no} < IR_{push} ($p = .012$), D ($p = .093$)
Appraisal of food pictures	65.30 (17.22)	63.05 (16.38)	65.53 (18.19)	62.79 (16.87)	64.10 (16.17)	$F(4,1000) = 1.07$, $p = .372$, $\eta_p^2 = .004$
Change in appraisal of food pictures (less positive)	2.04 (9.75) [***, $d = 0.21$]	3.75 (8.15) [****, $d = 0.46$]	5.11 (8.67) [****, $d = 0.59$]	3.54 (9.75) [****, $d = 0.36$]	5.27 (10.25) [****, $d = 0.51$]	$F(4,1000) = 4.17$, $p = .002$, $\eta_p^2 = .017$; C < Z ($p = .072$), IR_{push} ($p = .001$), D ($p < .001$); IR_{no} < IR_{push} ($p = .098$), D ($p = .062$)

Notes. Paired *t*-tests pre versus post intervention; n.s. = not significant; *p < .05, **p < .01, ***p < .005, ****p < .001.

obesity (i.e., greater than or equal to 30) was reached by 28.4% of the sample.

Craving for high-calorie food was initially moderate (M = 42.83, SD = 27.25). Overall, the food pictures were appraised rather positively (M = 63.80, SD = 17.21). Table 2 shows marked dissociations across conditions from baseline to post intervention. The largest reduction in craving by 17.95% was shown for IR_{push}, at a small to medium effect size for the baseline-post difference (paired test d = 0.36) followed by the zooming-out (12.94%, d = 0.28) and 3P/decoupling (11.74%, d = 0.29) conditions. IR_{push} was the only condition that differed significantly from the passive control condition (4.21%). While the IR_{no} group showed a significant decline in craving across time, this reduction did not differ significantly from the passive control condition. Moreover, the decline in the IR_{no} condition was smaller than in the IR_{push} (group difference: p = .012) and decoupling/3P (nonsignificant statistical trend, p = .093) conditions (PP analyses).

IR_{push} and decoupling/3P reduced positive appraisal of food pictures to a significantly larger extent than was found in the passive control group (see Table 2). In the ITT and PP analyses, the zooming out and IR_{no} conditions did not show a significantly stronger decline than for the control group.

For the ITT analysis, there was even a nonsignificant trend of a smaller decline with respect to food appraisal in the zooming-out compared to the decoupling/3P (p = .090) condition. IR_{no} was less efficient in reducing positive appraisal than decoupling/3P in the ITT analysis (p = .045) and PP analysis (nonsignificant statistical trend, p = .062). Results in the same direction emerged when comparing IR_{no} to IR_{push} (nonsignificant statistical trends; p = .073; p = .098).

For change in appraisal of food pictures, the differences between IR_{push} and 3P with the control condition would have survived a correction for multiple comparisons (both for the per protocol and ITT analyses).

The design had sufficient power (>.9) to detect a significant effect (*t*-test comparisons, p < .01 (because of multiple comparisons), one-sided) at a small-to-moderate effect size.

3.1. Moderation analyses

For exploratory purposes, we performed moderation analyses using the PROCESS macro by Hayes, which considered all baseline variables displayed in Tables 1 and 2 (see Table 3). For the FEV subscale Hunger (p = .008), those scoring high in the IR_{push} condition improved more than those in the decoupling/3P condition. Likewise, those in the IR_{push} condition who made the most positive appraisals of the food pictures improved more than those in the decoupling/3P condition (p = .031).

When comparing IR_{push} with the passive control condition, craving emerged as a significant moderator (p = .049), with higher craving leading to more substantial decline in the IR_{push} than in the control group. Weight also proved to be a moderator (p = .024): Higher weight in the IR_{push} condition was associated with a significantly greater decline compared to the control group. Regarding eating behavior, FEV Hunger, FEV Disinhibition, and FCQ Triggers were moderators (p = .002; p = .028; p = .029). Individuals in the IR_{push} condition scoring high on these subscales showed significantly greater decline than those in the control group.

Participants in the decoupling/3P condition showed similar moderators to those in the IR_{push} condition compared to the passive control group. Those with higher weight (p = .043) and BMI (p = .014) in the decoupling/3P condition showed a greater decline in craving. Apart from that, the FCQ subscale Triggers showed a nonsignificant trend for moderation (p = .073).

In the zooming-out condition, age bordered on significance (p = .050): Younger people in this condition showed a greater decline than those in the passive control group. Again, BMI moderated results (p = .026) in the same direction as in the decoupling/3P condition.

4. Discussion

Craving for high-calorie food is a major contributor to obesity and thus a core driver of debilitating and life-shortening disorders (Koliaki et al., 2019; La Sala & Pontiroli, 2020). Reducing craving can thus prevent several somatic but also psychological problems and may thus have important positive health implications beyond reduced food consumption (Verzijl et al., 2018). An initial RCT (Moritz, Paulus, et al.,

Table 3
Moderator analyses.

Variable	Coefficient	Standard Error	*t*	*p*	LLCI	ULCI	1 Standard Deviation Below Mean	Mean	1 Standard Deviation Above Mean
IR_{push} versus decoupling/3P									
Craving pre	1.075	0.640	1.680	.094	−0.182	2.332	.990	.097	.019
FEV Hunger	1.372	0.518	2.648	.008	0.353	2.390	.337	.198	.006
Food Appraisal pre	0.234	0.108	2.168	.031	0.022	0.446	.538	.193	.015
Control vs. IR_{push}									
Weight [kg]	0.213	0.094	2.265	.024	0.028	0.398	.535	.002	<.001
BMI	0.552	0.306	1.804	.072	−0.050	1.154	.323	.001	<.001
Craving pre	1.225	0.620	1.975	.049	0.006	2.444	.249	<.001	<.001
FCQ-T-R Triggers	3.348	1.532	2.185	.029	0.337	6.360	.526	.002	<.001
FEV Disinhibition	1.000	0.455	2.198	.028	0.106	1.895	.498	.002	<.001
FEV Hunger	1.545	0.507	3.049	.002	0.549	2.541	.919	.002	<.001
Control vs. Decoupling/3P									
Weight [kg]	0.163	0.080	2.031	.043	0.005	0.321	.974	.038	.004
BMI	0.670	0.272	2.461	.014	0.135	1.204	.797	.036	.001
FCQ-T-R Triggers	2.481	1.381	1.797	.073	−0.232	5.195	.877	.044	.007
Control vs. Zooming Out									
Age [years]	−0.243	0.124	−1.962	.050	−0.487	0.000	.007	.065	.939
Weight [kg]	0.147	0.083	1.767	.078	−0.017	0.311	.913	.055	.009
BMI	0.609	0.273	2.228	.026	0.072	1.145	.830	.055	.003

Notes. BMI = body mass index, *FCQ-T-R = Food Cravings Questionnaire-Trait-reduced, FEV = Three-Factor Eating Questionnaire; LLCI = lower limit confidence interval, ULCI = upper limit confidence interval.*

2019) and a subsequent dismantling study (Wirtz et al., 2021) provided some evidence for the effectiveness of IR, specifically throwing away from oneself high-calorie food in one's imagination with (IR_{push}) or without (IR_{no}) actually performing the arm movement (motor component). Other elements such as performing a pull movement for healthy food or zooming out seemed dispensable, according to the dismantling study. The present study addressed weaknesses of prior studies, such as the recruitment of women only and the small sample size in the dismantling study. In addition, for the first time, we examined a new technique called 3P that merges IR_{push} with decoupling in people with high craving, which in individuals with problematic alcohol use was more effective than the original variant (Moritz, Göritz, & Gehlenborg, 2022).

The present study corroborated the efficacy of imaginal retraining with a motor component (i.e., Moritz, Göritz, & Gehlenborg, 2022) and 3P (pull-pause-push), while imaginal retraining without a motor component, which had yielded promising results in the first dismantling study, showed reliable but inferior effects. Zooming out showed some effects on craving but did not dampen participants' appraisal of food pictures. 3P led to a smaller decline in immediate craving for high-calorie food in comparison to the study on individuals with problematic alcohol use (Moritz, Göritz, & Gehlenborg, 2022) but showed good effects for the appraisal of food pictures. We can at this point only speculate about the reasons. We assume that eating high-calorie food differs from drinking and smoking by having a less dominant pull element that is characteristic of the 3P technique. Of note, with alcohol the hand needs to be lifted during drinking in most instances, but this is less true for smoking because during inhalation the cigarette can be moved away from the mouth. When eating high-calorie food, the hand may even not be close to the mouth. In future studies, a 3 × 3 factorial design with substance (alcohol, tobacco, high-calorie food) and conditions (3P, imaginal retraining, control) may shed light on this issue, preferably in the framework of a within-subject design with randomization (i.e., all participants perform all three conditions in random order).

Of note, the techniques seem to be especially effective for those with greater problems, that is, people with higher weight/BMI (IR_{push}, decoupling/3P, zooming out), greater craving (especially for IR_{push}), and more dysfunctional eating behavior as indexed by the FEV and FCQ (especially for IR_{push}).

Apart from the aforementioned methodological limitations, other caveats need to be acknowledged. While studies on the original imaginal retraining paradigm suggest a lasting ameliorating effect on important behavioral outcomes such as weight, this needs to be rigorously retested with the present protocol as the push component is only one of several elements of the more complex imaginal retraining procedure. Future research should add objective outcomes such as externally determined weight loss, calorie intake, and clinician-rated instruments. We also need to develop credible control conditions that have similar demand characteristics as the experimental conditions. Such conditions may rule out that the positive effects of the experimental conditions relative to a passive control condition were due to higher instructional demands and complexity in the experimental condition. While we think this would represent an important improvement in design, we do not think that this argument can fully account for the present results as the 3P condition was the most complex condition with respect to movement but still was less effective compared to the imaginal retraining condition. Finally, we did not confine recruitment to people with obesity. Results, however, tentatively suggest that this group may benefit the most from the treatment.

To conclude, imaginal retraining, and to a lesser degree 3P, seem to represent viable behavioral strategies to resist immediate strong craving for high-calorie food and may thus represent a promising element in approaches to reduce craving. The results speak to the importance of embodiment in ABM.

Ethical statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and was approved by the ethics committee of psychologists at the University Medical Center Hamburg (Germany; number for ethical approval: LPEK-0440).

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Author contributions

Conceptualization, S.M, J.G., S.K.; methodology, all; formal analysis, S.M., J.G.; writing—original draft, S.M., J.G., S.K.; writing—review and editing, all.

Declaration of competing interest

The authors have developed the 3P technique which may be regarded as a conflict of interest (allegiance effect). There has been no external funding and all authors declare that they have no financial interests or benefits.

Data availability

Data will be made available on request.

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Not applicable.

Supplementary data

Supplementary data to this article can be found online at https://hdl.handle.net/21.11116/0000-000C-06C3-1.

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