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Imaginal Retraining Reduces Cigarette Smoking: A Randomized Controlled Study

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Keywords
Smoking · Approach-bias modification · Imaginal retraining · Craving

Abstract
Objectives: Smoking is a highly prevalent addictive behavior with severe and life-shortening health consequences. This is the first study to evaluate the efficacy of a newly developed imaginal variant of approach bias modification (ABM) (i.e., imaginal retraining) for the reduction of craving for tobacco and actual smoking behavior. ***Methods:*** We randomized 345 smokers to imaginal retraining (self-help manual) or a control group (either active control or wait-list control). Assessments were carried out online. The treatment interval was 6 weeks. Craving for tobacco represented the primary outcome. The study was registered as DRKS00016860. ***Results:*** Retention was 79.7% with no difference between groups. The intention-to-treat (ITT) analyses were significant for the primary outcome (Visual Analogue Scale on craving for tobacco) as well as subjective reduction of smoking (45.5 vs. 26.4%) in favor of imaginal retraining. In the treatment group, 47.6% performed the exercises at least once. This subgroup (per-protocol [PP] sample) showed a significant reduction in tobacco dependency as measured with the Cigarette Dependence Scale (short and long forms) and the Fagerström Test for Nicotine Dependence relative to controls. Number of daily cigarettes declined to a greater extent in imaginal retraining in the PP but not ITT analysis. A small dose-effect relationship emerged between craving and frequency of performance of the technique. ***Conclusion:*** When used regularly, imaginal retraining may reduce craving for tobacco and actual smoking behavior in a subgroup of smokers. In view of the large subgroup that did not read the manual or did not perform the exercises, alternative ways of conveying the imaginal retraining technique should be sought (e.g., demonstration via video clips). To conclude, imaginal retraining may represent a simple low-threshold technique to reduce smoking and assist current evidence-based treatment programs targeted at abstinence. It needs to be tested whether its mechanism of action deviates from standard ABM.

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Introduction

Consumption of tobacco is ingrained in Western culture and lifestyle [1], with a particularly high prevalence in Europe [2]. Adults have virtually unrestricted access to tobacco despite its well-established harmful and life-shortening consequences [3, 4]. Smoking is estimated to cause more than 6 million deaths worldwide per year and is responsible for a loss of approximately 150 million disability-adjusted life years worldwide [5].

Although smoking is on the decline in most countries, its prevalence remains high. Approximately 11.5% of global deaths are attributable to smoking, and smoking was ranked among the 5 leading risk factors by disability-adjusted life years in 109 countries and territories in 2015, leading to a call for enhanced political commitment and new treatment methods [6]. In a large epidemiological study with 12,273 participants in Germany [7], the 1-year prevalence of tobacco consumption was 28.3%; on average, the smokers had made 1 attempt to quit during the previous year. The most commonly used method of quitting was smoking e-cigarettes (9.1%). Only 12.5% applied evidence-based methods or used another kind of support; the largest group tried to quit on their own [7]. Yet, studies have shown that only a few "self-quitters" achieve prolonged abstinence periods [8, 9]. A longitudinal cohort study across different Western countries suggested that the high rate of failure to quit is largely attributable to psychological factors such as cue exposure, craving, withdrawal symptoms, and lack of smoking cessation aids [10]. These findings highlight the urgent need to develop evidence-based interventions that are broadly available.

Building upon dual-process theories [11, 12], addictions have been explained by an excess of (implicit) impulsive approach tendencies that override the (explicit) will to disengage from the behavior and the explicit insight into the harmful potential of a substance or behavior [13]. In keeping with these findings, experimental studies using the approach-avoidance task (AAT) show that addicted individuals are faster to pull a picture of their preferred drug toward themselves than to push it away via a joystick in a computerized setup compared to non-addicted individuals [14]. This effect is especially well-established in alcohol addiction, but similar findings have been obtained in smoking, too.

Following from studies on the approach-avoidance task, a retraining of attentional biases via approach bias modification (ABM) was developed, starting with hazardous drinkers [15]. The procedure was soon successfully implemented with other addictions [16]. In this interventional paradigm, the addictive substance or behavior is coupled with pushing a joystick, whereas a positive or neutral cue is coupled with pulling a joystick. This procedure is effective at a small effect size in decreasing relapses in alcohol dependence and in several studies also managed to override the approach bias usually observed in addicted individuals [16–18]. In individuals with eating disorders, ABM resulted in a medium change of the approach bias and small effects for food consumption and craving for high-calorie foods [19]. Yet, recent meta-analyses have cast doubt on the notion of the general effectiveness of the ABM approach in terms of proximal clinical outcomes (addiction and craving) [20, 21]. In the meta-analysis by Boffo et al. [21], cognitive bias modification exerted a small effect on cognitive bias and relapse rate but not on reduction of substance use. The evidence for smoking is encouraging but mixed in terms of reduction of cigarette consumption [22]. Two recent studies [23, 24] failed to obtain evidence for both short-term and long-term ABM effects on reduction of smoking and the putative underlying excessive approach bias for tobacco-related stimuli. In contrast, a study in psychiatric patients reported significant positive changes in the approach bias and long-term nicotine consumption (at 3-month follow-up) [25].

Although the ABM procedure is simple and can be performed as a self-help technique with no or minimal instructions by a clinician, it has several drawbacks [26]. First, the task is often considered boring and tedious [27], which may result in lower training effects due to disengagement or noncompliance. Another barrier to implementation into a daily routine is that it requires a computer device and a joystick. Moreover, there are constraints pertaining to the stimuli displayed [26]. For alcohol, in particular, there are no universal stimuli that induce craving in all problem drinkers. The type of beverage (e.g., wine), brand, and favorite method of consumption (e.g., can) differ across drinkers. In smokers, the specific brand and especially the environment of typical consumption are also difficult to personalize, even with large sets of pictures.

Imaginal retraining is a variant of classical ABM that aims to overcome some of the shortcomings of classical ABM (e.g., the requirement of a computer device). Following a simple negative mood induction designed to foster embodiment, the alleged primary mechanism of ABM [28], participants are instructed to throw (actual behavior/movement) the *imagined* addictive substance away (e.g., pack of cigarettes, can of beer, high-calorie food) or addiction-related objects (e.g., a slot machine). This sequence corresponds to the push movement in conven-

tional ABM. For the opposite sequence, the user engages in a positive mood induction before he or she imagines drinking or eating a tasty but non-addictive beverage or food while coupling this with other positive images to enhance the effects of embodiment (for a discussion of different theories on embodiment [28]). The concept of embodiment is actively conveyed to participants as a mode of action in the imaginal program, which may raise self-efficacy and thus ignite other more explicit psychological processes beyond bodily driven disgust.

In a recent randomized controlled trial involving 84 problem drinkers [26], imaginal retraining reduced craving at a large effect size. Self-esteem also improved in the retraining condition relative to controls: 75% of the individuals in the treatment group reported less alcohol consumption in the study period, whereas drinking behavior remained essentially unchanged in the control group. The study was, however, compromised by several limitations. Attrition in the retraining group was high (40.5%), and the manual contained some additional behavioral tips; as a result, we were unable to attribute the effects exclusively to imaginal retraining.

Following up on our previous findings, this is the first study to examine the effectiveness of imaginal retraining in smokers. To meet this purpose, we adapted the original manual for problem drinkers to smokers. To evaluate the effectiveness of the core technique more rigorously, we did not provide any additional recommendations on how to reduce smoking. Furthermore, we extended the intervention period from 4 to 6 weeks. We expected that imaginal retraining would reduce craving for tobacco (primary outcome) as well as reduce manifest smoking behavior. The control group was composed of a passive (wait-list) control group and an active control group. Finally, we conducted exploratory moderation analyses to examine factors that promote versus obstruct the effectiveness of the technique.

Methods

Sample

Recruitment for the web-based intervention was carried out via WisoPanel [29, 30], a participant pool of German-speaking people who have registered for participation in web-based studies (https://www.wisopanel.net). Members of WisoPanel are drawn from diverse sources, both online and offline, thus reducing selection biases.

In spring of 2019, 14,563 persons (8,836 women and 5,727 men) received a link to the study. The group comprised both smokers and nonsmokers. After a short description of the purpose of the study and its inclusion criteria, interested people were asked to give their explicit informed consent. The study was advertised as an unguided treatment study for smokers. It was set up as a randomized controlled trial; controls were allowed access to standard care. Study participation was anonymous. Participants in the intervention condition received the imaginal retraining manual immediately after randomization via an e-mail attachment, whereas participants in the control condition received the manual upon completion of the post-assessment.

Inclusion criteria were age between 18 and 75 years and self-reported current smoking. No formal diagnosis of tobacco dependence nor fulfillment of any threshold criteria was mandatory. Acute suicidality (as measured by a score of 2 or 3 on the BDI-II rating for suicidal ideation) led to exclusion. Concurrent treatments were tolerated (see Table 1).

Data from 345 participants were included for the final analyses. The main reasons for exclusion of data were premature cancellation, declining to give informed consent, and no current smoking (see Fig. 1). The control condition had 2 arms: a wait-list control (participants received full access to the intervention at post-assessment) arm and an active control. The allocation ratio for the intervention and the control groups was 2:1:1 (retraining vs. active and wait-list control). For the active control condition, participants were encouraged to download and use an app developed by our research group to improve self-esteem and mood (called MCT & More), which has been shown to be effective to improve mood in depressed patients [31]. The trial was registered with the German Clinical Trials Register (DRKS00016860).

Invitation and Baseline Survey

Assessments were carried out online using Questback/UniPark®. Following the guidelines of the European General Data Protection Regulation (GDPR), no IP addresses were stored. Ethical approval was obtained from the local ethics committee for psychologists at the University Hospital of Hamburg-Eppendorf (Germany) prior to the start of the trial (LPEK-0023). As an incentive, all participants received a self-help manual on imagery rescripting [32] upon completion of the post-survey as well as a link to the MCT & More app. At the beginning, we asked for electronic informed consent, which was mandatory. Questions on the participant's demographics and their medical history (e.g., prior experience with psychotherapy, prior psychiatric diagnoses, if any) followed. Next, smoking and other psychological scales were administered. Shortly before the end of the assessment, we asked participants whether they had answered all questions truthfully, and we requested an anonymous e-mail address as well as a personal code word. The e-mail addresses were not stored online. Within 48 h, participants were randomized to 1 of the 3 conditions (the allocation was implemented based on the date of participation as displayed in the so-called "trigger e-mail"). Owing to the online setup of the study, concealed allocation could not be implemented as in traditional clinical trials with face-to-face assessments. Our procedure is best characterized as centralized assignment. There is no risk of bias with this procedure as the person allocating individuals to the conditions had no information about the participants other than the date they signed up for the study.

Participants in the control group were informed that they would receive the retraining manual after the post-assessment. Six weeks after initial participation, all participants were invited to participate in the post-assessment. Up to 3 reminders were e-mailed (3–4 days apart). For the post-assessment, participants were first asked to re-enter their e-mail address and their personal code word. The same set of questionnaires was administered as in the baseline survey. For those who had received the manual and

Table 1. Sociodemographic and smoking-relevant characteristics of the 3 subgroups (N_{tot} = 345)

	Wait-list (n = 96)	Active control (n = 78)	Retraining (n = 171)	
Sociodemographic variables				
Age in years	50.22 (12.28)	47.40 (11.97)	48.25 (11.43)	$F(2, 342) = 1.39$, $p = 0.251$, $\eta_p^2 = 0.008$
Year of formal school education	11.38 (1.66)	10.96 (1.66)	10.98 (1.65)	$F(2, 342) = 2.06$, $p = 0.130$, $\eta_p^2 = 0.012$
Gender (% female)	67.7	43.6	56.1	$\chi^2(2) = 10.21$, $p = 0.006$
Employed full time (%)	44.8	59	50.9	$\chi^2(2) = 3.47$, $p = 0.113$
Smoking-relevant information				
VAS craving	58.85 (27.14)	60.00 (29.11)	57.43 (29.11)	$F(2, 342) = 0.24$, $p = 0.783$, $\eta_p^2 = 0.001$
VAS strength	65.42 (27.68)	69.10 (24.77)	61.23 (29.55)	$F(2, 342) = 2.25$, $p = 0.107$, $\eta_p^2 = 0.013$
VAS frequency	59.06 (27.19)	60.13 (28.72)	58.25 (30.03)	$F(2, 342) = 1.08$, $p = 0.340$, $\eta_p^2 = 0.001$
CDS-12	40.70 (10.43)	42.37 (10.97)	40.16 (11.63)	$F(2, 342) = 1.06$, $p = 0.347$, $\eta_p^2 = 0.006$
CDS-5	16.39 (4.55)	16.78 (4.74)	16.44 (4.91)	$F(2, 342) = 0.17$, $p = 0.839$, $\eta_p^2 = 0.001$
Daily cigarettes	13.36 (7.69)	14.63 (8.97)	14.65 (13.64)	$F(2, 342) = 0.45$, $p = 0.639$, $\eta_p^2 = 0.003$
Attempts to quit smoking	3.22 (1.43)	2.88 (1.43)	3.05 (1.54)	$F(2, 342) = 1.09$, $p = 0.336$, $\eta_p^2 = 0.006$
FTND	3.43 (2.49)	4.00 (2.35)	3.65 (2.57)	$F(2, 342) = 1.34$, $p = 0.323$, $\eta_p^2 = 0.007$
Currently no treatment for smoking, %	87.5	87.2	78.9	$\chi^2(2) = 4.36$, $p = 0.113$
Well-being				
BDI	10.82 (10.08)	13.94 (12.08)	11.58 (9.91)	$F(2, 342) = 2.05$, $p = 0.130$, $\eta_p^2 = 0.012$
QoL	3.47 (0.83)	3.41 (0.89)	3.38 (0.90)	$F(2, 342) = 0.21$, $p = 0.732$, $\eta_p^2 = 0.002$

BDI, Beck Depression Inventory; CDS-12, Cigarette Dependence Scale (12 items); CDS-5, Cigarette Dependence Scale (abbreviated 5-item scale); FTND, Fagerström Test for Nicotine Dependence; QoL, WHOQOL-BREF global item; VAS, Visual Analogue Scale.

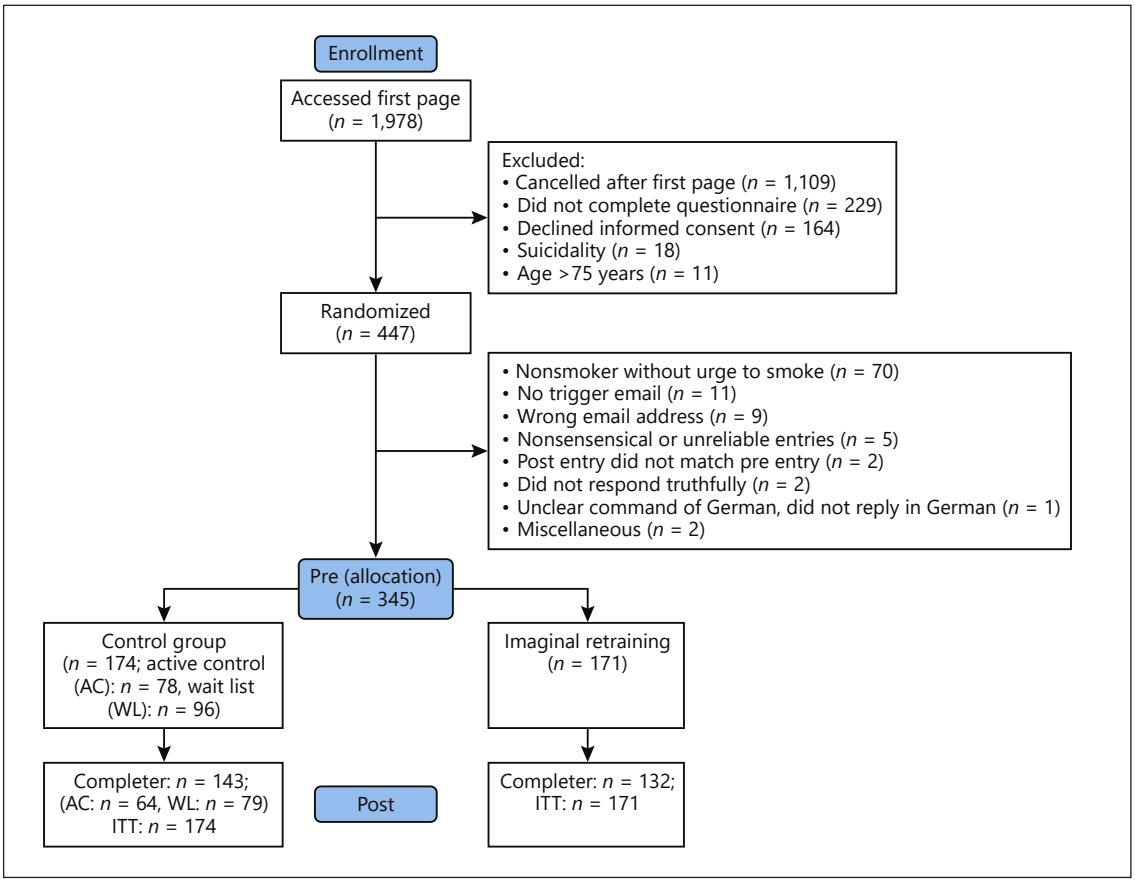
who indicated that they had at least started to read it (response options: did not read manual, read the manual at least partially but did not perform the exercises, performed the exercises once during the intervention period, performed the exercises once a week, performed the exercises several times a week, performed the exercises on a daily basis, performed the exercises several times a day), we posed further questions related to subjective quality, comprehensibility, satisfaction, and subjective efficacy.

Imaginal Retraining

Imaginal retraining is a manualized, stepped intervention (10 pages with 3 figures; 4,426 words). The manual first welcomes the reader and gives a brief introduction to the purpose of the manual. This is followed by a psychoeducational section that highlights well-established consequences of smoking. In the subsequent chapters, we familiarize participants with the classical approach-avoidance procedure and its effects. To enhance participants' understanding of the rationale of our procedure, we explain the psychological mechanisms that experts believe underlie conventional retraining.

Before imaginal retraining is explained, in vivo exposure and in sensu exposure are described, as the latter is an essential part of our procedure. The participants are then instructed to imagine their preferred smoking brand and habitual way of smoking. Next, they are asked to imagine something they like to eat or drink (e.g., eating an apple and drinking fresh mineral water). In this part, we also inform participants about the close connection between body posture, thoughts, and emotions (broadly referred to as embodied cognition theory). We explain that when we are depressed, we often walk slumped over and with the corners of our mouths turned down, whereas when we feel proud and are in a good mood, we usually walk with a more upright body posture and tend to have a confident or even joyful facial expression. Participants are told that posture and emotion influence each other reciprocally; thus, straightening the body leads to a slight improvement in mood, whereas having a bent-over posture "darkens" our thoughts. We then provide specific instructions for the exercises. Imaginal retraining contains 2 steps. For the aversive part (negative affective conditioning), the person should first exhale and slump forward. They should round their shoulders, and this posture should be reinforced as vividly as possible with negative thoughts. Following this, they should think of their favorite brand of cigarettes (a pack or single cigarettes). Imagining being at a place where they often smoke, they should then push or throw away the cigarettes in their imagination (e.g., throwing them from a balcony), while vigorously executing the actual movement. This sequence is illustrated in the manual (see online suppl. Figure; see www.karger.com/doi/10.1159/000509823 for all online suppl. material). We also advise participants to throw the imagined cigarettes onto the ground because pushing away and downward movements are typically associated with disgust. They may also imagine possible negative consequences, such as a hole burned in the carpet.

For the pleasant sequence, participants are asked to imagine eating an apple or drinking a glass of water. They are then asked to take a deep breath and stand up straight and tall, as if someone were pulling them up by an imaginary thread attached to the top of their head. Thereafter, they should move the imagined healthy food or drink toward their mouth in an exaggerated way, as portrayed in many advertisements, so that they are looking slightly



Color version available online

Fig. 1. CONSORT flowchart for the current study. ITT, intention-to-treat analysis; AC, active control; WL, wait-list control.

upward (this is introduced as a means to improve mood). At the same time, they should contemplate pleasant thoughts and images (e.g., drinking water while stroking a pet lying against their chest). A drawing illustrates this procedure (see online Appendix). Participants are asked to perform this second exercise regularly as well, but the manual does not impose a strict "recipe" or order for the 2 contrasting sequences.

Participants are encouraged to use an alarm device to remind them to perform the exercises at least twice a day. Unlike the previous manual for problem drinkers [26], no further tips were provided.

QuestionnairesPrimary Outcome

Visual Analogue Scale (VAS). As in our pilot study [26], the total score of the VAS served as the primary outcome and measured craving for cigarettes during the previous week. For scoring, the participant moves a bar between 0 and 100 {strength of smoking craving in nonsmoking phases (not at all [=0] to very strong [=100]); strongest craving for cigarettes (not at all [=0] to very strong [=100]); frequency of craving for cigarettes (never [=0] to always [=100])}. The composite score contained the mean value for craving during nonsmoking phases and the frequency of craving cigarettes.

Secondary Outcomes

Cigarette Dependence Scale (CDS-12, CDS-5) [33]. The CDS-12 is a self-rating questionnaire assessing nicotine dependency according to DSM-IV and ICD-10 criteria. We administered both the longer version of the CDS (12 items), and the shorter version (5 items). The validity and reliability are good [34, 35].

Fagerström Test for Nicotine Dependence (FTND) [36]. This self-rating questionnaire is composed of 6 questions measuring the severity of addiction, with scores ranging from 0 (= low dependence) to 10 (= very strong dependence), and it has been shown to be reliable [37]. Studies indicate that the FTND is inferior to the CDS-12 in terms of predictive and construct validity [34].

WHO Quality of Life (WHOQOL-BREF) [38]. The global item of the WHOQOL-BREF was used an index of quality of life.

Beck Depression Inventory II (BDI-II; [39]). The BDI-II is considered the gold standard for the measurement of depression and contains 21 items that tap into common somatic and psychological symptoms of depression. The internal consistency and test-retest reliability of the German version are good [40].

Moderator Variables

Willingness to change was assessed at baseline with a subset of items from the University of Rhode Island Change Assessment (URICA; [41]). The questionnaire has satisfactory reliability [42,

Table 2. Group differences across time (ITT and PP analyses). Significant pre-post paired comparisons are given in parentheses

Variable	Control group		IR		PP sample (IR)	Statistics ITT (multiple imputation)	Statistics PP
	pre (n = 174)	post (n = 143)	pre (n = 171)	post (n = 132)	difference (n = 40)		
VAS	59.45 (25.63)	55.14 (55.14)*	57.84 (28.45)	48.71 (25.28)**	14.62 (26.78)***	$B = -4.76$, $t = -2.21$, $p = 0.027$	$F(1, 181) = 7.25$, $p = 0.008$, $\eta_p^2 = 0.039$
CDS-12	41.45 (10.68)	38.55 (11.58)****	40.16 (11.63)	36.51 (11.36)****	6.00 (11.19)***	$B = -1.50$, $t = -1.54$, $p = 0.123$	$F(1, 181) = 6.00$, $p = 0.015$, $\eta_p^2 = 0.032$
CDS-5	16.56 (4.62)	15.62 (4.67)***	16.44 (4.91)	14.94 (4.94)****	2.37 (4.28)****	$B = -0.783$, $t = -2.187$, $p = 0.029$	$F(1, 181) = 9.20$, $p = 0.003$, $\eta_p^2 = 0.048$
Daily cigarettes	13.93 (8.29)	11.46 (12.87)*	14.65 (13.64)	11.12 (11.27)*	7.10 (20.87)*	$B = 0.940$, $t = 0.90$, $p = 0.366$	$F(1, 181) = 4.23$, $p = 0.041$, $\eta_p^2 = 0.023$
FTND	3.68 (2.44)	3.21 (2.55)*	3.65 (2.57)	3.22 (2.43)***	1.00 (1.80)****	$B = -158$, $t = -0.80$, $p = 0.425$	$F(1, 181) = 5.84$, $p = 0.017$, $\eta_p^2 = 0.031$
BDI	12.22 (11.09)	4.24 (5.71)****	11.58 (9.91)	3.42 (4.40)****	8.87 (7.11)****	$B = -0.545$, $t = -1.17$, $p = 0.243$	$F(1, 181) = 0.83$, $p = 0.362$, $\eta_p^2 = 0.005$
QoL	3.44 (0.86)	3.44 (0.86)	3.38 (0.90)	3.47 (0.96)	−0.10 (0.84)	$B = 0.07$, $t = 0.82$, $p = 0.414$	$F(1, 181) = 0.87$, $p = 0.352$, $\eta_p^2 = 0.005$

ITT, intention-to-treat; PP, per-protocol; IR, imaginal retraining. * $p \leq 0.05$. ** $p \leq 0.01$. *** $p \leq 0.005$. **** $p \leq 0.001$.

43]. Expectations regarding the success of the intervention were measured with a single item (1 = not successful at all; 9 = very successful). Items were entered separately in the moderation analyses.

Subjective Appraisal and Benefit

Participants who had read the manual were asked to fill out the Patient Satisfaction Questionnaire (German acronym ZUF-8; [44]), adapted for online interventions. The ZUF-8 assesses subjective appraisal of the technique (e.g., quality, satisfaction, effectiveness, and intention to use the application in the future). The 2 tables in the online Appendix show the results of these and additional questions regarding the treatment.

Results

Baseline Characteristics and Compliance

Table 1 presents the sociodemographic and smoking-relevant characteristics of the 3 subgroups at baseline. Most participants were in their late 40 s (M = 48.50, SD = 11.81), with slightly more women than men participating (56.5 vs. 43.5%). Most people had attempted to quit smoking several times (M = 3.06, SD = 1.49). According to self-report, participants smoked 14.29 (SD = 11.25) cigarettes daily.

Since the 2 control groups did not differ on the primary outcome ($p = 0.796$), presumably because the active control condition was rarely used ($n = 7$ used the app), we pooled the 2 control conditions. The combined group did not differ from imaginal retraining on gender distribution ($\chi^2(1) = 0.02$, $p = 0.887$) nor any baseline characteristics (see Table 1, $t < 0.12$, $p > 0.2$). Only the second craving item (strength) bordered on significance ($t = 1.94$, $p = 0.054$) with participants in the experimental group scoring somewhat lower ($p > 0.5$ for the other items).

Of those in the experimental group who rated their adherence at post, 8.5% acknowledged that they had not read the manual at all and 43.9% reported they had read the manual at least partially but had not performed the exercises. 24.4% had performed the exercises once in the intervention period or once a week; 17.1% had performed the exercises several times a week, with 1 participant (1.2%) who had performed the exercises on a daily basis; and 4.9% had performed the exercises several times daily. Thus, 47.6% had performed the exercises at least once during the study period. The completion rate was 79.7% with no difference between the control groups (pooled: 82.2%) and the retraining group (77.2%, $\chi^2(1) = 1.328$, $p = 0.249$).

Of the controls, 26.4% had smoked less during the intervention period according to self-report compared to 45.5% in the experimental group, $\chi^2(1) = 10.93$, $p = 0.001$. The latter rate rose to 59% when considering only those

Table 3. Significant moderators of the between-group differences between the CDS total and VAS composite scores (pre-post) across time. Significance is displayed for different levels (i.e., low, medium, and high scores)

Variable	Coefficient	SE	*t*	*p*	LLCI	ULCI	*p* difference depending on value of moderator		
							low (−1 SD)	medium (0)	high (+1 SD)
Outcome: VAS									
QoL	−1.025	0.374	−2.741	0.007	−1.762	−0.287	0.527	0.002	0.000
URICA 4	0.900	0.331	2.721	0.007	0.247	1.554	0.000	0.023	0.848
URICA 7	0.847	0.348	2.437	0.016	0.161	1.533	0.000	0.011	0.885
BDI	0.102	0.039	2.637	0.009	0.026	0.179	0.000	0.000	0.976
Outcome: CDS-12									
VAS 1	−1.041	0.501	−2.078	0.039	−2.029	−0.052	0.901	0.020	0.002
VAS 2	−1.204	0.550	−2.416	0.017	−2.188	−0.220	0.729	0.004	0.000
URICA 1	−2.988	1.392	−2.147	0.033	−5.734	−0.341	0.375	0.002	0.001
URICA 5	−3.216	1.133	−2.839	0.005	−5.451	−0.981	0.689	0.001	0.000
URICA 6	−2.792	1.092	−2.557	0.011	−4.946	−0.637	0.948	0.049	0.001
CDS-12	−0.263	0.126	−2.083	0.039	−0.512	−0.014	0.914	0.009	0.002
CDS-5	−0.630	0.294	−2.139	0.034	−1.211	−0.049	0.886	0.007	0.002
BDI	0.294	0.140	2.100	0.037	0.018	0.571	0.002	0.002	0.856

URICA: 1 = I think I might be ready for some self-improvement; 4 = I guess I have faults, but there is nothing that I really need to change; 5 = I have a problem and I really think I should work on it; 6 = I have started working on my problems but I would like help; 7 = I may be part of the problem, but I don't really think I am. LLCI, lower limit confidence interval; ULCI, upper limit confidence interval; VAS, Visual Analogue Scale.

who had performed the exercises at least once, $\chi^2(1) = 14.66$, $p < 0.001$.

Test-Retest Reliability

Test-retest reliability was acceptable to good for the CDS-5 ($r = 0.802$), FTND ($r = 0.793$), CDS-12 ($r = 0.746$), and BDI ($r = 0.702$). Reliability of the QoL($r = 0.669$) and the VAS composite score ($r = 0.634$) was satisfactory (all $p < 0.001$).

Group Differences across Time

Group differences were calculated using mixed ANOVAs with group as the between-subject and time as the within-subject factor. The intention-to-treat (ITT) and per-protocol (PP) results are displayed in Table 1 as well as significant within-subject effects. The ITT analyses with multiple imputation were significant for the primary outcome (VAS composite score) and the CDS-5 in favor of imaginal retraining. No significant difference emerged for any of the other measures. In the PP analyses considering only those who had performed the exercises at least once ($n = 40$), significant differences occurred in favor of imaginal retraining with a small or small to medium effect size for the VAS composite score, CDS-12, CDS-5, FTND, and number of cigarettes smoked daily (in addition, there were significant within-subject effects in the experimental group). Quality of life remained unchanged for both the between-subject and within-subject analyses. Importantly, in the PP analyses, the treatment group differed from both the active controls ($p = 0.013$) and the wait-list condition ($p = 0.018$) on the primary outcome.

The frequency of performance positively correlated with reduction in craving ($r = 0.28$, $p = 0.012$), CDS-12 ($r = 0.28$, $p = 0.012$), CDS-5 ($r = 0.263$, $p = 0.017$), and FTND ($r = 0.30$, $p = 0.006$) (Table 2).

Completers versus Non-Completers

Completers had higher scores than non-completers on item 5 of the URICA ("I have a problem and I really think I should work on it"), $t(343) = 1.43$, $p = 0.049$.

Moderation

Table 3 displays the results of the exploratory moderator analyses, including all sociodemographic and psychometric baseline variables displayed in Table 1 as well as the URICA items and the item related to expectation. Participants low on well-being showed less benefit in the intervention relative to controls. Those scoring high on craving and dependency (VAS and CDS total scores) in the experimental group improved more on the CDS-12 but not on the VAS composite score. Insight and readiness to change, as measured by URICA items 1, 5, and 6,

differentially improved the outcome for the imaginal retraining group (CDS-12); fatalism and lack of insight, as measured by URICA items 4 and 7, decreased the outcome in this group (analyses with the VAS).

Subjective Appraisal

The 2 tables in the online Appendix display the subjective appraisal of the participants in the experimental group who had performed the exercises at least once. In square brackets are figures from our forerunner trial on imaginal retraining in problem drinkers for use as a benchmark. We comment on the differences to the benchmark if they are larger than 10%, which occurred in 3 out of 17 comparisons. More than 80% of the participants endorsed the following statements: good or excellent quality of the manual, would recommend the manual to a friend, good for self-help, comprehensible, and helpful. Between 70 and 79% endorsed the following statements: happy about the extent of help received from the manual, would use manual again, and manual would have made more sense if it was used together with psychotherapy (fewer than in the pilot trial with problem drinkers). Between 60 and 69% endorsed the following statements: expected type of treatment received, manual helped cope with problems more successfully (fewer than in the pilot trial with problem drinkers), cigarette consumption decreased because of the program, ability to use the manual on a regular basis (fewer than in the pilot trial with problem drinkers), and that participant had to force himself or herself to use the manual; 46.2% endorsed that the manual was not applicable to their smoking behavior.

Discussion

Imaginal retraining [26] is a simple technique that, unlike conventional ABM, does not necessitate a computer device and allows for greater personalization of stimuli via imagination (e.g., imaging one's favorite brand and the customary smoking environment).

The present study demonstrated that imaginal retraining reduces craving for tobacco and cigarette consumption in those who actually performed the exercises at least once in the intervention period (47.6% of participants in the retraining sample; completers). The ITT that considered all participants irrespective of adherence and completion revealed that craving, dependency (as measured with the CDS-5), and subjective reduction of smoking (45.5 vs. 26.4%) were reduced significantly.

Unlike many prior studies [23, 45, 46], we found evidence of a dosage effect, which was small: more practice led to stronger effects. Reading the manual but not performing the exercises was apparently not sufficient to yield an effect. The majority of users would recommend the technique to a friend. Approximately 74% would use the manual again, but fewer participants than in our prior benchmark study of problem drinkers [26] practiced the exercises regularly (self-report; 66.7 vs. 86.4%). The study thus essentially corroborates the results of our prior study, but we need to explain why the effects were somewhat smaller than those observed in drinkers. First, approach-avoidance biases have been tested in both problem drinkers and smokers, and there is emerging evidence that pathological approach behavior is larger in the former group; some studies even failed to detect an approach bias in smokers at all [23, 24]. Relatedly, results for conventional retraining seem to be more promising in problem drinkers than in smokers. Second, the intervention period was larger in the present study than in the benchmark study (6 vs. 4 weeks), and the effects of retraining may diminish over time. Third, the prior study of problem drinkers was smaller, and the participants in the former study differed in core baseline characteristics, which along with some worsening in the control group may have contributed to a slight overestimation of the effect. Fourth, selection biases may have played a role. For the present study, we approached participants from a closed forum of participants in the general population and e-mailed them directly, whereas the prior study recruited problem drinkers via social media and other Internet campaigns, which may have attracted the attention of individuals with a stronger desire to stop their addictive behavior (i.e., a higher degree of self-selection). Fifth, after a brief psychoeducation chapter on the consequences of smoking, the present manual confined itself to teaching participants how to perform imaginal retraining; no other advice was provided. In contrast, the imaginal retraining manual for problem drinkers gave some additional recommendations such as interval drinking (drinking a nonalcoholic beverage after an alcoholic beverage). The impact of these additional tips is elusive, but we cannot rule out that they augmented the observed effect.

As mentioned previously, only a minority of participants in the experimental group studied the manual and performed the exercises. We therefore need to consider new ways to promote the technique and motivate subjects to engage with it more frequently. We received feedback from some users who found the manual too long. Clips posted via social media providing clear and entertaining

instructions (e.g., animations showing how the exercises ought to be executed and film sequences offering possible images) may be more appealing to users and improve comprehensibility and adherence. In basic research, it is important to flesh out the potential of single techniques, but we also need to test whether adding further behavioral tips to the manual (as was done in the manual for problem drinkers) may enhance the effect. In addition, whether imaginal retraining exerts an add-on effect to established programs should be tested. A recent study [24], for example, did not detect such an add-on effect for conventional ABM retraining.

We need to acknowledge several limitations. First, we have no follow-up data to show how sustainable the effects are over time. Second, because the study was set up as a self-help trial, we had to rely on subjective feedback. However, acceptable test-retest reliability and high retention rates speak for the quality of the data, and checks of the integrity of the data suggest that the data are trustworthy. An advantage of anonymous self-help research is that allegiance effects may play a minor role compared to face-to-face trials, where participants may exaggerate the experienced benefits to, for example, express gratitude. Yet, telephone interviews and objective markers of smoking may help to validate subjective ratings in future trials. For example, assessment of psychiatric disorders, particularly substance use disorder, should be undertaken more rigorously. Third, imaginal retraining is a multifaceted technique, and we need to elucidate the mechanisms of action. While the present data suggest that reading the manual is insufficient to elicit an effect, the relative contribution of the mood-induction procedure and the approach sequences to the outcome are unclear. For example, it has not yet been tested whether imagining performing the behavior (or watching someone else performing it) is sufficient to elicit an effect. ABM and imaginal retraining show differences in other aspects as well. The very explicit nature of retraining in sensu, particularly the employment of embodiment – including an explanation why imaginal retraining might work – may ignite other processes compared to ABM. For ethical reasons, we refrained from introducing a sham condition as is often done in conventional retraining studies. The possible side effects of an imaginal sham condition where smoking or drinking is simulated need to be tested rigorously before implementation. Finally, the effects of imaginal retraining on cognitive biases such as overattention to smoking cues and excessive approach behavior have not yet been tested.

Conclusions

Imaginal retraining led to a significant reduction in manifest smoking behavior and craving over a period of 6 weeks in those who used the technique. The more often the technique was performed, the greater was the reduction in craving. Future studies should investigate the long-term effectiveness of the technique and, given the large number of participants who chose not to read the manual, alternative ways of promoting the technique should be tested. The technique should also be examined in other substance addictions (e.g., cannabis) or behavior addictions (e.g., pathological gambling). Finally, dismantling studies are needed to pinpoint mechanisms of change.

Statement of Ethics

Subjects (adults ≥18 years) have given their written informed consent. The study protocol has been approved by the research institute's committee on human research (LPEK University of Hamburg, ethics committee; approval number: LPEK-0023). The study was registered as DRKS00016860.

Conflict of Interest Statement

The authors have no conflicts of interest to declare. Importantly, the technique under investigation is available at no cost precluding any financial conflict of interest.

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Author Contributions

All authors have contributed substantially to the manuscript and proofread and approved the final version of the manuscript. Their involvement fully justified inclusion as coauthors.

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