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Imaginal Retraining Reduces Craving for Tobacco in 1-Year Controlled Follow-Up Study

Josefine Gehlenborg[a] Anja S. Göritz[b] Steffen Moritz[a] Thies Lüdtke[a] Simone Kühn[a, c]

[a]Department of Psychiatry and Psychotherapy, University Medical Centre Hamburg-Eppendorf (UKE), Hamburg, Germany; [b]Department of Occupational and Consumer Psychology, University of Freiburg, Freiburg, Germany; [c]Lise Meitner Group for Environmental Neuroscience, Max Planck Institute for Human Development, Berlin, Germany

Keywords
Imaginal retraining · Smoking · Approach bias · Self-help · Craving

Abstract
Introduction: Imaginal retraining is a self-help technique that adapts the principles of approach bias modification to the imagination. Imaginal retraining has been shown to reduce craving and addictive behaviours in 3 randomized controlled trials (RCTs) on problematic alcohol consumption, overweight, and tobacco use. To date, there have been no studies evaluating the long-term efficacy of the intervention. The aim of the present study was to generate first hypotheses on the long-term efficacy of imaginal retraining in smokers in a controlled 1-year follow-up study. ***Materials and Methods:*** We recontacted the 345 participants who had taken part in an RCT on imaginal retraining for smokers 1 year later. The survey was carried out online and assessed craving for tobacco (primary outcome), smoking behaviour, well-being, and subjective appraisal. Individuals who applied the technique at least once during the previous year were categorized as the training group, whereas participants who never performed the training were categorized as the no-training group. Data were analysed using linear mixed models (LMMs). The study was preregistered as DRKS00021044. ***Results:*** The completion rate was 45.5%. Less than 40% used the intervention at least once in the previous 12 months. LMM analyses showed a significant reduction in craving for tobacco for the training compared to the no-training group after 1 year. No significant group differences emerged in smoking behaviour, depressive symptoms, or quality of life. Subjective appraisal of the intervention was favorable, similar to the initial study. ***Conclusion:*** The present study provides preliminary support for the long-term efficacy of imaginal retraining on craving for tobacco but not on smoking behaviour, highlighting the importance of multimodal treatment concepts in smoking cessation that target a variety of maintaining factors. Future studies need to investigate the long-term efficacy of the intervention in prospective RCTs that test alternative ways of conveying the technique to improve adherence.

karger@karger.com
www.karger.com/ear

Correspondence to:
Josefine Gehlenborg, j.gehlenborg@uke.de

Introduction

Tobacco is a widely used recreational drug in Western countries, and adults have unrestricted access to it [1]. Despite declining prevalence rates, 23.6% of adults worldwide are still consuming tobacco [2]. Moreover, secondary exposure to tobacco smoke remains a serious problem [3]. In 2015, approximately 150 million disability-adjusted life years were attributed to tobacco consumption, and 6.4 million people worldwide died due to smoking, representing 11.5% of global deaths [4]. Tobacco use is among the main risk factors for cardiovascular disease, chronic respiratory disease, diabetes mellitus, and cancer [5], the 4 major non-communicable diseases worldwide that account for more than 32 million annual deaths [2].

According to a recent representative study in Germany [6], 28.5% of smokers had tried to quit smoking at least once during the previous year, but only 12.5% of this population applied evidence-based methods for smoking cessation. Almost 60% tried to achieve abstinence by relying on their willpower alone. However, only 3–5% of self-quitters achieve long-term abstinence [7]. The use of professional support predicts successful smoking cessation [8], while not using cessation aids is associated with relapse [9], emphasizing the need for accessible, low-threshold, evidence-based interventions. One of the main reasons for not seeking psychological treatment is the desire to solve the problem on one's own [10]. The dissemination of evidence-based self-help interventions may be an economical way to counteract these treatment barriers [11, 12]. Building on patients' wish to cope with their problems on their own, self-help interventions may increase motivation to initiate and maintain treatment and perceptions of self-efficacy. In tobacco use disorder in particular, one of the most common barriers to care is consumers' perception that achieving abstinence is challenging and will likely fail [13]. Guiding patients to help themselves and supporting them in ceasing smoking by means of manualized self-help interventions may mitigate these fears.

Among the cessation aids that hold promise, among other things, approach bias modification (ABM) has recently been the centre of attention. ABM is a computer-based training aimed at reducing craving by manipulating automatic approach tendencies towards addiction-related stimuli and by changing implicit cognitions [14]. Craving, namely, the strong urge to consume a certain substance, is a defining symptom in tobacco use disorder [15] and is believed to contribute to high relapse rates in smokers [9, 16, 17]. Thus, reduction in craving is deemed pivotal in smoking cessation and an important mechanism of change in tobacco use disorder. In ABM, participants are shown addiction-related and -unrelated pictures on a computer screen [18]. Using a joystick, they are asked to push away addiction-related pictures and to pull towards themselves addiction-unrelated pictures. Instructions may be implicit (e.g., telling participants to respond to a landscape vs. a portrait format of the picture) or explicit (i.e., directly telling participants to push away addiction-related pictures) [19, 20]. Depending on the joystick's movement, pictures in the pull condition become larger, whereas pictures in the push condition become smaller (zooming). Smokers' behaviour is characterized by pathological approach tendencies towards cigarette-related cues [21, 22]. By retraining these automatic action tendencies, ABM has been shown to reduce neural cue reactivity of the amygdala [23], which is substantially involved in the cognitive processes (i.e., associative learning) underlying craving [24]. Studies report reduced craving and other smoking-related behaviours in inpatient [25] and outpatient [26] as well as Web-based settings [27, 28] after ABM compared to sham training. However, some studies report null findings [29] or inconsistent results [30] or even question the clinical utility of ABM [31]. Moreover, patients' acceptance of computer training is low [32, 33], which might be detrimental to treatment motivation and compliance. Therefore, novel interventions are needed that are more appealing to patients.

Recently, we developed an imaginal self-help variant of ABM known as imaginal retraining to adapt the basic principles of ABM to the imagination [34]. In short, participants are instructed to create mental scenarios where individually relevant craving-related stimuli are pushed or thrown away but non-craving-related stimuli are approached by mentally visualizing consuming them (for a detailed description of the approach, see Methods section). Shifting ABM into the realm of the imagination may have several advantages over the computer-based variant. No computer device is needed to conduct imaginal retraining, which makes implementation of ABM more feasible in daily life. Moreover, it allows for individualization as participants are free to choose the craving-related substance or object to imagine. People with pathological approach tendencies towards certain substances or behaviours differ greatly in terms of the stimuli that trigger these tendencies. For example, the usual way they consume tobacco (e.g., cigarettes, e-cigarettes, and smokeless tobacco) and their

preferred brand or product (e.g., menthol cigarettes and cigarillos) vary among individuals with tobacco use disorder. Moreover, participants become involved in the training by generating their own mental scenario. Personalization of the objects used in the training likely improves participants' motivation and treatment outcome as prolonged changes in behaviour are most likely to occur if a new program is fun and easily implemented [35].

Imaginal retraining previously has been shown to reduce craving and addiction-related behaviours in 3 RCTs [34, 36, 37]. In a first study of individuals with self-reported alcohol problems [34], the imaginal retraining group significantly improved in self-reported alcohol craving (large effect size), alcohol consumption (moderate effect size), and self-esteem (small effect size) compared to the wait list control group with access to care as usual after 4 weeks. In a second study of overweight/obese women [36], the imaginal retraining group significantly improved at small effect sizes in self-reported food craving, trait craving, and eating behaviour compared to the control group. Moreover, a subgroup that was instructed to use electronic reminders to do the exercises significantly reduced weight compared to the control group. In a different RCT of 345 smokers [37], participants in the intervention group reported significantly reduced craving for tobacco and smoking behaviour at small effect sizes compared to the control group after an intervention period of 6 weeks. In all 3 RCTs, depressive symptoms and quality of life did not differ between groups after training. Moreover, exploratory moderation analyses revealed that participants in the intervention group who scored high on quality of life, low on depressive symptoms, or high on readiness for change benefited most from the intervention.

These results suggest that imaginal retraining may be a promising treatment approach for unhealthy behaviours, such as alcohol consumption, smoking, and unhealthy eating. Yet, it remains unclear whether the effects are enduring as no data have been available on long-term effects of imaginal retraining. The present study is a controlled 1-year follow-up assessment of the aforementioned RCT on imaginal retraining in smokers. We aimed to assess usage of the self-help technique in the previous year and participants' symptomatology and satisfaction with the treatment 1 year after initial participation to generate first hypotheses about the long-term efficacy of imaginal retraining. Findings will serve as a basis for conducting a long-term RCT in the future.

Materials and Methods

Design and Procedure

The current study was conducted as a 1-year follow-up assessment of an RCT that evaluated the efficacy of a newly developed imaginal variant of ABM (imaginal retraining with an 11-page self-help manual) compared to a wait list and an active control condition over a period of 6 weeks [37]. In the initial RCT, no long-term follow-up assessment was planned. We recontacted via e-mail the participants who had taken part in the initial study and invited them to participate in the 1-year follow-up study to generate first hypotheses about the long-term efficacy of the intervention as the basis for a future confirmatory study. As all participants received access to the intervention after completion of the post-survey of the RCT, for the present study group, allocation was based on self-reported use of the intervention over the previous 12 months. Individuals who applied the technique at least once during the previous year were categorized as the training group, whereas participants who did not perform the training were categorized as the no-training group. Due to this post hoc group allocation, participants were not independently and randomly sampled in this follow-up study. Group allocation was done in accordance with the trial registration of this study.

The study invitation provided a link to the online survey, which was implemented using the software Unipark® (EFS survey). Both the initial and the follow-up study were preregistered (DRKS00016860, DRKS00021044) and were approved by the Local Ethics Committee for psychologists at the University Medical Centre Hamburg-Eppendorf, Germany (LPEK-0023, LPEK-0104). Participation in the follow-up trial was voluntary, and all participants gave electronic informed consent. As an incentive for participation in the new study, participants received a self-help manual on relaxation techniques.

Participants

A total of 345 participants (56.5% female) aged 18–75 years (M = 48.50, standard deviation (SD) = 11.81) with self-reported smoking (cigarettes per day: M = 14.29, SD = 11.25), a desire to reduce their tobacco consumption, and no acute suicidality were included in the initial study [37]. On average, they showed moderate craving for cigarettes (Visual Analogue Scale (VAS): M = 60.49, SD = 26.45, range = 0–100), moderate dependence symptoms (Fagerström Test for Nicotine Dependency: M = 3.67, SD = 2.50), and minimal depressive symptoms (Beck Depression Inventory II: M = 11.90, SD = 10.52). They were randomized to the intervention group, an active control group (app to improve self-esteem and mood), or a wait list control group (ratio: 2:1:1) for an intervention period of 6 weeks. However, since only 7 individuals used the app and the 2 control conditions did not differ on craving for tobacco (primary outcome), the intervention group was compared to a pooled control condition. Participation in the baseline assessment of the initial RCT was mandatory for inclusion in the present follow-up study.

Intervention

Imaginal retraining is a self-help technique that adapts the basic principles of ABM to the imagination, eliminating the need for a computer. In imaginal retraining for smoking cessation, people are instructed to imagine their favourite type of cigarette in a context where they often smoke it. The imagination technique in-

cludes negative mood induction, in which participants are instructed to exhale, slump forward with rounded and sloping shoulders, and consciously reinforce this posture with negative thoughts. This serves to enhance aversive associations with smoking. Next, the participants are told to push the cigarette away in their imagination while carrying out the actual movement with their body (e.g., acting as if they are throwing their preferred type of cigarette on the floor of their local pub). After this avoidance phase (the push condition), participants are asked to perform another sequence in which they pull pleasant (healthy and non-craved) objects towards themselves. This time (the pull condition), they are instructed to imagine a pleasant object (e.g., healthy beverage/food) and then perform a positive mood induction by standing up straight in a relaxed posture. The participant then moves the pleasant object towards their mouth in their imagination and with an actual body movement while looking slightly upwards. Participants were instructed to set a timer using their smartphone reminding them to perform the exercises 2 times a day for approximately 10 min. The order and frequency of the push and pull trials could be determined by the participants depending on personal preferences and benefits. (For more detailed information on the self-help technique and the structure of the intervention manual, including illustrations of the approach and avoidance sequences, see the initial study [37].)

Outcomes

Primary Outcome

Visual Analogue Scale. As in the initial study, a composite mean score of 3 visual analogue scales assessing craving for cigarettes during the past week served as the primary outcome. On a scale of 0–100, participants rated intensity of their craving for cigarettes in non-smoking phases ("not at all" to "very strong"), intensity of their strongest craving for cigarettes ("not at all" to "very strong"), and frequency of their craving for cigarettes ("never" to "always").

Secondary Outcomes

Cigarette Dependence Scale (CDS-12 and CDS-5) [38]. We administered both the 12-item long version and the 5-item short version of the Cigarette Dependence Scale (CDS) to measure nicotine dependency. The CDS showed good reliability and validity in previous studies [39, 40]. The items are linked to DSM-IV and ICD-10 criteria and represent cigarette dependence on a continuum, with higher scores indicating higher likelihood of dependence.

Fagerström Test for Nicotine Dependency [41]. The Fagerström Test for Nicotine Dependency (FTND) is a 6-item self-report questionnaire assessing relevant dimensions of nicotine dependency. The total score can range from 0 to 10 (0–2 = low dependence; 3–4 = moderate dependence; 5–6 = strong dependence; and 7–10 = very strong dependence). Psychometric properties of the scale have been shown to be good [42].

Beck Depression Inventory II [43]. The Beck Depression Inventory II (BDI-II) is composed of 21 items assessing depressive symptoms. In the present study, the German version was used, which showed high internal consistency and good test-retest reliability in previous studies [44]. BDI-II scores are categorized as minimal (9–13), mild (14–19), moderate (20–28), and severe depression (29–63). Scores <9 indicate the absence of clinically relevant depressive symptoms.

WHO Quality of Life [45]. As an index of participants' quality of life, the global item of the WHO Quality of Life (WHOQOL-BREF) ("How would you rate your quality of life"?) was administered (5-point scale from "very bad" to "very good").

Patient Satisfaction Questionnaire (German Acronym ZUF-8) [46]. The ZUF-8 assesses satisfaction with treatment using 8 items (e.g., quality, effectiveness, and intention to use in the future). Items can be answered on a 4-point scale. Reliability and validity have been shown to be good [47, 48].

Subjective Appraisal. Nine items assessing patients' subjective appraisal of the self-help technique were administered (e.g., suitability for self-help, consumption reduction, and comprehensibility). Items could be answered on a 5-point scale ranging from "does not apply at all" to "totally apply."

Baseline Questionnaires. At baseline, patients' readiness for change was assessed using a subset of the German version of the University of Rhode Island Change Assessment Scale (URICA) [49]. The URICA includes 3 subscales (precontemplation, contemplation, and action) based on the transtheoretical model of change by Prochaska and DiClemente. Treatment expectations were assessed using a single item (1 = "not at all successful" to 9 = "very successful"). These measures were not administered in the follow-up survey, but the data assessed at baseline were used to describe sample characteristics. (For further information on these measures, see the initial study [37].)

Statistical Methods

In accordance with the initial trial, we planned to conduct repeated measures analyses of variance (ANOVAs) with time as the within-subject factor and group as between-subject factor. However, the assumptions for this type of analysis were not fulfilled due to heterogeneous residual variances and covariance matrixes. Moreover, points of measurements were not timed equidistantly, impeding the use of repeated measures ANOVA. Due to the violations of statistical assumptions of ANOVA, we chose to calculate linear mixed-effects models (LMMs) using IBM SPSS 26®. The LMM is the method of choice for analysing clustered data that violate the assumption of independence of observations [48, 49]. We specified a 2-level structure, with individual change over time in outcomes at level 1 and group as between-subject factors at level 2. Variables on which groups differed significantly at baseline and the initial group allocation (experimental vs. control condition) were included in the model as fixed covariates. Restricted maximum likelihood estimation was used for parameter estimation. Four different covariance structures for repeated measures and random effects were tested (unstructured, diagonal, compound symmetry, and scaled identity). We chose covariance structures that provided the best model fit. For each primary and secondary outcome, we calculated a model with random intercept and time and group interaction as predictors. The time variable was coded in weeks (0, 6, and 52 weeks) to account for missing equidistance. Random slopes were tested for each model. We compared the model fit of fixed and random slope models and models with different covariance structures using likelihood ratio tests.

Results

Completion Rate and Usage

A total of 157 participants took part in the follow-up assessment (completion rate: 45.5%). The majority

Table 1. Baseline group differences in sociodemographic and psychopathological characteristics

Variable	Full sample (n = 157)	Training (n = 59)	No-training (n = 98)	Statistics
Sociodemographic variables				
Age, years	49.25 (11.43)	47.61 (12.38)	50.24 (10.77)	t (155) = 1.40, p = 0.163
Years of formal school education	11.09 (1.67)	11.00 (1.65)	11.14 (1.69)	t (155) = 0.52, p = 0.605
Gender (female), %	54.1	55.9	53.1	χ^2 (1) = 0.12, p = 0.727
Employed full-time, %	47.8	47.5	48.0	χ^2 (1) < 0.01, p = 0.951
Smoking-relevant information				
VAS craving	55.86 (29.98)	58.81 (30.40)	54.08 (29.74)	t (155) = 0.96, p = 0.340
VAS strength	62.48 (30.40)	68.14 (30.37)	59.08 (30.05)	t (155) = 1.82, p = 0.071
VAS frequency	55.10 (31.80)	61.69 (32.12)	51.12 (31.09)	t (155) = 2.04, p = 0.043
CDS-12	39.54 (11.98)	40.44 (12.42)	39.00 (11.74)	t (155) = 0.73, p = 0.467
CDS-5	16.19 (4.97)	16.63 (5.07)	15.93 (4.92)	t (155) = 0.85, p = 0.396
FTND	3.42 (2.45)	3.54 (2.46)	3.34 (2.45)	t (155) = 0.48, p = 0.630
Currently no treatment for smoking, %	84.7	81.4	86.7	χ^2 (1) = 0.82, p = 0.364
Motivation and expectations				
Motivation to quit, %				
Very motivated	19.7	22.0	18.4	
Motivated	26.1	33.9	21.4	
Partly motivated	28.0	28.8	27.6	χ^2 (4) = 6.77, p = 0.148
Not very motivated	9.6	5.1	12.2	
Not motivated	16.6	10.2	20.4	
URICA precontemplation	2.46 (0.92)	2.56 (0.91)	2.40 (0.92)	t (155) = 1.07, p = 0.287
URICA contemplation	3.41 (1.08)	3.75 (1.00)	3.21 (1.08)	t (155) = 3.07, p = 0.003
URICA action	3.60 (0.79)	3.76 (0.70)	3.50 (0.82)	t (155) = 2.05, p = 0.042
CEQ	5.18 (1.96)	5.83 (1.68)	4.80 (2.02)	t (155) = 3.30, p = 0.001
Well-being				
BDI-II	9.11 (9.40)	10.42 (10.22)	8.33 (8.83)	t (155) = 1.36, p = 0.176
QoL	3.51 (0.88)	3.42 (0.90)	3.56 (0.87)	t (155) = 0.95, p = 0.346

Means and *SD*s (in brackets) or percentages. BDI-II, Beck Depression Inventory (second version); CDS-12, Cigarette Dependence Scale (12 items); CDS-5, Cigarette Dependence Scale (abbreviated 5-item scale); FTND, Fagerström Test for Nicotine Dependence; QoL, quality of life; VAS, Visual Analogue Scale; URICA, University of Rhode Island Change Assessment Scale; CEQ, Credibility Expectancy Questionnaire; *SD*s, standard deviations.

(62.4%) of the participants did not read the entire manual and did not perform the exercises (no-training group, n = 98) in the previous 12 months; 37.6% used the intervention at least once in the previous 12 months (training group, n = 59). Approximately one-third (35.6%) of the training group performed the exercises at least once a month. On average, the self-help technique was used 31.61 days (*SD* = 66.99) by the training group in the previous year. Among individuals in the training group, 62.7% (n = 37) originally were randomized to the intervention group at baseline, and 37.2% (n = 22) to the control groups (active control: 22.0%, n = 13; wait list: 15.3%, n = 9). Among individuals in the no-training group, 43.8% (n = 43) originally were randomized to the intervention group at baseline and 56.1% (n = 55) to the control groups (active control: 23.5%, n = 23; wait list: 32.7%, n = 32).

Baseline Characteristics and Group Differences

Baseline characteristics of the overall follow-up sample of both training and the no-training groups are displayed in Table 1. The training group experienced a higher frequency of craving episodes as measured with the VAS than the no-training group. No significant group differences emerged on any other smoking-related or well-being-related measure. Treatment expectations were higher in the training group. Moreover, the training group displayed higher scores on 2 URICA subscales which belong to the stages of change "contemplation" (i.e., awareness of the existence of a dysfunctional behaviour) and "action" (i.e., initiation of active measures to change behaviour or environment) of the model by Prochaska and colleagues [50].

Table 2. Symptom change over time

Variable	Baseline	Post	Follow-up	Group* time interaction
VAS				
Training	62.88 (29.36)	51.07 (27.18)	47.97 (26.77)	$B = -0.231$, SE = 0.069, t (165.464) = −3.338, $p = 0.001$ (−0.368; −0.094)
No-training	54.76 (28.43)	55.00 (24.99)	52.21 (27.45)	
CDS-5				
Training	16.63 (5.07)	14.73 (5.32)	14.90 (5.15)	$B = -0.018$, SE = 0.009, t (169.661) = −1.917, $p = 0.057$ (−0.036; 0.001)
No-training	15.93 (4.92)	15.28 (4.89)	15.37 (5.24)	
CDS-12				
Training	40.44 (12.42)	35.77 (12.62)	36.19 (12.32)	$B = -0.041$, SE = 0.025, t (165.817) = −1.639, $p = 0.103$ (−0.091; 0.008)
No-training	39.00 (11.74)	37.90 (11.23)	37.27 (12.73)	
FTND				
Training	3.54 (2.46)	2.82 (2.47)	3.22 (3.02)	$B = 0.005$, SE = 0.005, t (166.071) = 0.947, $p = 0.345$ (−0.005; 0.015)
No-training	3.35 (2.45)	3.15 (2.36)	2.93 (2.42)	
BDI-II				
Training	12.61 (9.53)	4.60 (4.95)	10.42 (10.22)	$B = -0.004$, SE = 0.027, t (301.599) = −0.135, $p = 0.892$ (−0.057; −0.050)
No-training	10.12 (9.26)	2.61 (3.76)	8.33 (8.83)	
QoL				
Training	3.42 (0.89)	3.30 (0.99)	3.49 (0.92)	$B = 0.004$, SE = 0.002, t (176.015) = 1.732, $p = 0.085$ (−0.006; 0.009)
No-training	3.56 (0.87)	3.57 (0.86)	3.47 (0.89)	

Means and *SD*s (in brackets). Results of LMMs (group* time interaction) with unstandardized regression coefficients (*B*), *SE*, *t* statistics, and CI. QoL: global item of the WHOQOL-BREF. Controlled for: baseline scores on VAS strength, VAS frequency, URICA contemplation, URICA action, and CEQ. BDI-II, Beck Depression Inventory (second version); CDS-12, Cigarette Dependence Scale (12 items); CDS-5, Cigarette Dependence Scale (abbreviated 5-item scale); FTND, Fagerström Test for Nicotine Dependence; VAS, Visual Analogue Scale; *SE*, standard error; CI, confidence interval; LMMs, linear mixed effects models.

Smoking Behaviour

The training group reported a mean number of daily cigarettes of 13.78 (*SD* = 9.44) at baseline and 12.58 (*SD* = 12.10) at follow-up. The no-training group reported similar cigarette consumption (baseline: *M* = 12.89, *SD* = 8.73; follow-up: *M* = 11.55, *SD* = 8.62). Changes in the number of daily cigarettes did not differ between groups ($t(73.87) = 0.09$, $p = 0.929$). In the training group, 37.3% reported having smoked less, 47.5% reported having smoked approximately the same amount, and 15.3% reported having smoked more in the previous year. In the no-training group, 21.4% reported having smoked less, 63.3% reported having smoked approximately the same amount, and 15.3% reported having smoked more in the previous year. Of those reporting a reduction in smoking behaviour in the previous year, 31.8% in the training group attributed the change to the use of imaginal retraining, 9.1% to the SARS-CoV-2 pandemic, 4.5% to the use of other smoking cessation aids, and 31.8% to other reasons. In the no-training group, subjective reasons for reductions in smoking behaviour were the SARS-CoV-2 pandemic (28.6%), the use of other smoking cessation aids (14.3%), and other reasons (33.3%).

Group Differences in Symptom Change over Time

Symptom change over time was analysed using the LMM. For the primary outcome, a random intercept random slope model provided the best model fit ($\chi^2(1) = 13.69$, $p < 0.001$). As the inclusion of a random slope in model calculation did not significantly improve model fit for any secondary outcome measure, we used random intercept fixed slope models for all secondary outcomes (for CDS-5, CDS-12, and FTND, random slope estimation was not possible with one of the a priori selected random covariance structures: WHOQOL-BREF ($\chi^2(1) = 0.08$, $p = 0.775$). For the BDI-II, the inclusion of a random slope even led to a significantly worse model fit ($\chi^2(1) = 54.62$, $p < 0.001$). Parameter estimates of LMM analyses are displayed in Table 2. For the primary outcome, the model showed a significant interaction effect of time and group ($B = -0.231$, t [165.464] = −3.338, $p = 0.001$), indicating that the training group experienced a greater reduction in VAS mean scores over time than the no-training group. Correlation analyses showed that a higher frequency of performance (days of training in the last 12 months) of imaginal retraining exercises in the last 12 months was associated with a greater reduction of craving from base-

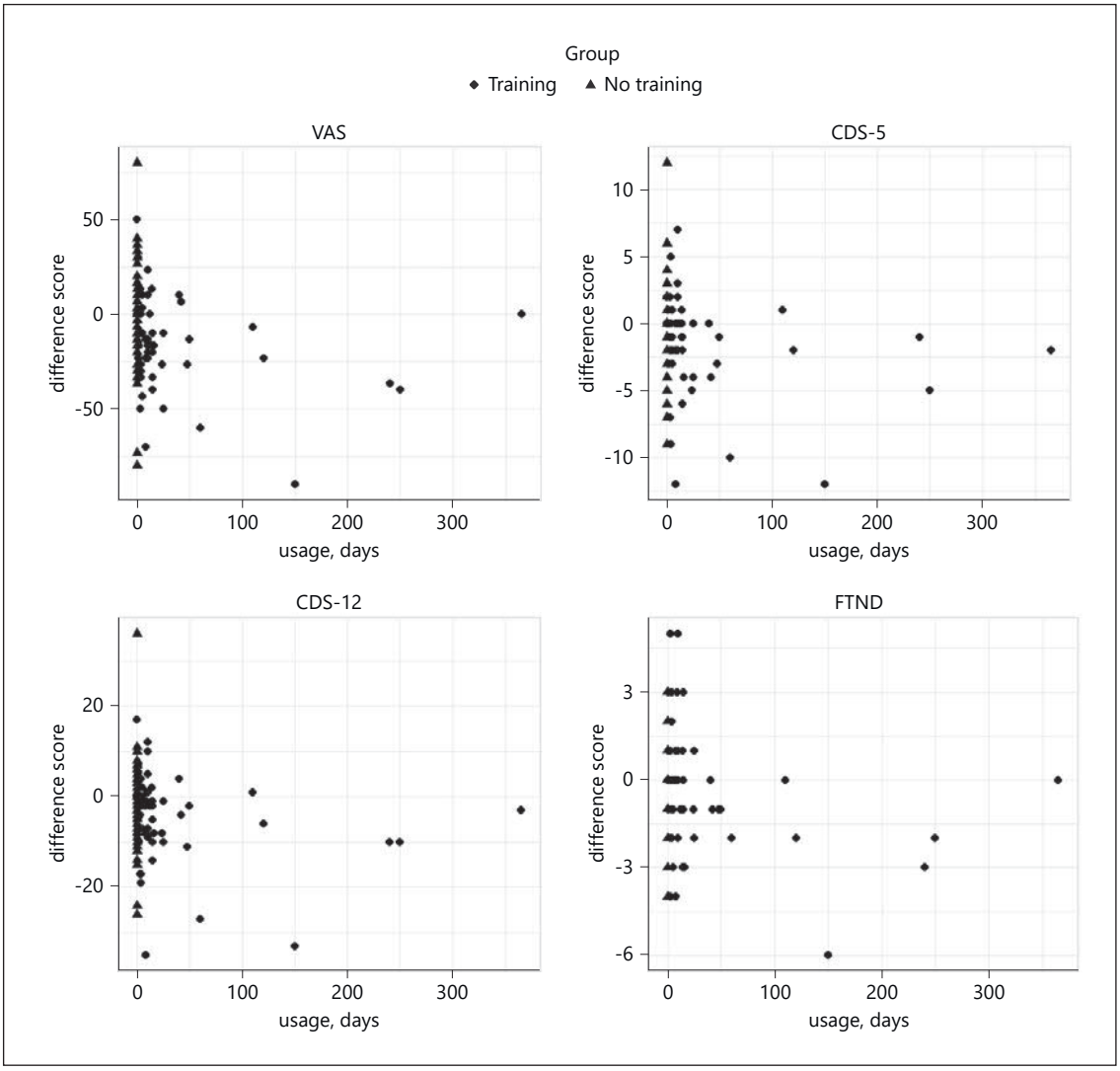

Fig. 1. Scatter plots of frequency of training (days) in the previous year and symptom reductions from baseline to follow-up assessment. Note: Negative scores indicate symptom reductions in the respective measure. VAS, Visual Analogue Scale; CDS-5, CDS-12, Cigarette Dependence Scale short and long versions; FTND, Fagerström Test for Nicotine Dependency.

line to follow-up assessment at a small effect size (r = −0.224, p = 0.005), implying a dosage effect. No significant interaction effects were found on any secondary outcome measure. However, significant correlations for frequency of training and reduction in smoking behaviour as measured with the CDS-5 (r = −0.180, p = 0.024), CDS-12 (r = −0.187, p = 0.019), and FTND (r = −0.180, p = 0.024) emerged with small effect sizes. Scatter plots of frequency of training and reductions on the VAS, CDS-5, CDS-12, and FTND are displayed in Figure 1.

Subjective Appraisal and Satisfaction with Treatment

Subjective appraisal and satisfaction with treatment (ZUF-8) are displayed in Tables 3 and 4. We comment on results if differences in scores from the initial study are >10%, which occurred for 3 items of the subjective appraisal questionnaire but none of the ZUF-8 items. Compared to the 6-week post-assessment of the initial study, in the 1-year follow-up survey, fewer participants reported being able to use the manual on a regular basis (50.8% vs. 66.7%), more participants reported having to force themselves to use the manual (78.0% vs. 61.5%), and

Table 3. Patients' satisfaction with imaginal retraining (adapted version of the ZUF-8)

Item	Training (n = 57)	
	mean (*SD*)	positive appraisal, %
How do you rate the quality of the manual? (excellent (1), good (2) vs. less good (3), not good (4))	1.96 (0.64)	81.8
Did you receive the type of treatment you expected to receive? (not at all (1), not really (2) vs. in general yes (3), yes absolutely (4))	2.80 (0.88)	68.5
To what extent did the manual meet your needs? (it nearly met all my needs (1), it met most of my needs (2) vs. it met a few of my needs (3), it did not meet my needs (4))	2.42 (0.91)	59.7
Would you recommend the manual to a friend with similar symptoms? (definitely not (1), probably not (2) vs. probably yes (3), absolutely (4))	3.19 (0.80)	83.3
How happy are you about the extent of the help you have received through using the manual? (dissatisfied (1), somewhat dissatisfied (2) vs. mostly satisfied (3), very satisfied (4))	3.07 (0.80)	79.6
Did the manual help you cope with your problems more successfully? (yes, it helped me absolutely (1), yes, it helped me a little (2) vs. no, it did not help me that much (3), no, it did not help me at all (4))	2.43 (0.84)	53.7
How satisfied are you with the manual in general? (very satisfied (1), mostly satisfied (2) vs. somewhat unsatisfied (3), unsatisfied (4))	2.23 (0.88)	67.3
Would you use the manual again? (definitely not (1), probably not (2) vs. probably yes (3), yes (4))	3.09 (0.79)	77.4

Missing values: n = 2. ZUF-8, Patient Satisfaction Questionnaire; *SD*, standard deviation.

Table 4. Subjective appraisal of imaginal retraining

Item	Training (n = 59)	
	mean (*SD*)	endorsement (absolutely applies through applies a little), %
I think the manual is good for self-help and self-guidance.	2.05 (1.04)	91.5
My cigarette consumption decreased because of the application of the program.	2.59 (0.87)	62.7
I think the content of the manual was comprehensible.	3.02 (0.90)	93.2
I think the manual was helpful.	2.76 (0.90)	93.2
I was able to use the manual on a regular basis.	1.86 (1.04)	50.8
I had to force myself to use the manual.	2.34 (0.98)	78.0
I think the manual would make more sense if it were used in combination with psychotherapy.	2.63 (0.96)	84.7
The manual is not applicable to my smoking behaviour.	1.85 (0.87)	57.6
I smoked less because of the manual.	2.05 (1.04)	61.0

Scores range from 1 (not at all) to 4 (absolutely). *SD*, standard deviation.

more participants endorsed the statement that the manual was not applicable to their smoking behaviour (57.6% vs. 46.2%).

Discussion/Conclusion

Main Findings

We conducted a controlled 1-year follow-up study to generate first hypotheses on the long-term efficacy of imaginal retraining, a novel self-help imaginal variant of ABM. As hypothesized, LMM analyses showed a significant reduction in craving as measured with the VAS in the training group compared to the no-training group. No significant symptom reductions occurred on any secondary outcome measure. In the initial study, participants in the intervention group of the per-protocol sample showed significant reductions in the VAS mean score, CDS-5, CDS-12, and FTND after the 6-week intervention period [37]. Imaginal retraining therefore

seems to have the potential to reduce craving for cigarette smoking in the long term but may only affect smoking behaviour in the short term. These findings are in line with a recent meta-analysis showing that cognitive bias modification interventions such as ABM lead to a reduction in cognitive biases (i.e., approach bias) and relapse rates but not in substance use [51]. This may be due to the fact that even though craving and approach biases are deemed relevant risk factors for cigarette smoking [16, 17, 21, 22], other factors contribute to the maintenance of smoking behaviour. For example, some authors argue that cigarette smoking is primarily sustained as a result of positive and negative reinforcement processes, with positive effects occurring immediately and negative consequences being undetermined and distant in time [52]. We conclude that a primary mechanism of imaginal retraining that needs to be tested in future RCTs may be the reduction of craving for substance-relevant stimuli, which in turn may lead to a reduction in smoking behaviour in the short term. In the long term, however, other factors may counteract these influences (e.g., reinforcement processes [52] or metabolic alterations [53]) that are not addressed by approach-avoidance training interventions.

To the best of our knowledge, there have been no studies examining the 1-year efficacy of computer-based ABM for smoking cessation. Machulska and colleagues [25] found a significant reduction in nicotine consumption at 3 months after training. Wittekind and colleagues [28] conducted a 6-month follow-up assessment of Web-based ABM training without support for the long-term efficacy of the intervention. Craving was not assessed at follow-up in either of the studies. Due to heterogeneous outcome measures and time points of follow-up assessments as well as frequency and setting of training sessions, comparing our results to findings on the long-term efficacy of computer-based ABM remains difficult.

In line with previous studies [36, 37], we found a dosage effect indicating that higher frequency of use of imaginal retraining was associated with greater reduction in craving. At the same time, the unsatisfactory frequency of training from baseline to post-assessment (47.6% performed the exercises at least once in the 6-week intervention period) was even lower at the 1-year follow-up. Only 37.6% of follow-up participants used the self-help technique at least once in the previous 12 months, and only approximately one-third of the training group conducted the training at least once a month. It remains uncertain whether more frequent use of the intervention may have an effect on smoking behaviour. Arguing for this effect, correlation analyses show that higher frequency of training was associated with greater reduction in smoking behaviour as measured by the CDS-5, CDS-12, and FTND scores. Low frequency and motivation to use the intervention were also reflected in participants' subjective appraisal of the self-help technique. Compared to the 6-week post-assessment, self-reported regular performance and motivation to use imaginal retraining had decreased 1 year later. Since the majority of the participants did not read the self-help manual at all or only partially, we assume that the low training frequency may not be due to features of the intervention, as in computer-based ABM [32, 54], but that the method of instructing participants (a written 11-page manual) may be detrimental to compliance. In addition, ambivalence regarding treatment motivation, which is typical for individuals with substance use problems [55, 56], may have influenced the uptake of the intervention. However, for those participants who did read the manual and performed the exercises at least once, low training frequency may also be due to the nature of the training. One reviewer suggested that "imagining and "acting out" exercises might not appeal to all participants. Whether this assumption is true and some participants might have concerns about imaginal retraining exercises need to be investigated in future studies. Moreover, future studies should investigate whether the use of more appealing and user-friendly instruments (e.g., a video tutorial) and the integration of motivational components might increase frequency of use. Another research question that should be investigated in future studies is the utility of imaginal retraining in cravings for other substances. As discussed in the introduction, in addition to craving for cigarettes, the efficacy of imaginal retraining has been assessed in craving for alcohol and craving for high-calorie foods. Long-term effects in these subgroups still need to be evaluated. Moreover, investigating the efficacy of imaginal retraining in craving for illicit drugs might be an interesting topic for future research.

Limitations

The present study had some limitations that need to be acknowledged. Firstly, the randomized group allocation from the initial study was not used in the follow-up assessment as all participants had received access to the intervention after the 6-week post-assessment. Group allocation was based on self-reported use of the intervention during the previous year. Although we con-

trolled for baseline differences between the training and the no-training groups in LMM analyses, other differences between groups may have had an effect on symptom reduction and may have biased LMM as well as correlation analyses. Future studies need to include long-term follow-up assessments and maintain randomization until after the end of all assessments. Secondly, retention of participants was not satisfactory which is a typical problem of online training studies [20, 27, 28]. Only 45.5% of participants who completed the baseline survey of the initial study completed the follow-up assessment. Therefore, study results may be influenced by self-selection of participants. Thirdly, we did not measure approach bias at any measurement time point. Studies investigating computer-based approach-avoidance training showed that reduction in craving is mediated by retraining of a pathological approach bias [57, 58], which we assume is also the case for imaginal retraining. Future research examining effects of imaginal retraining on approach bias in smokers is needed to further understand the underlying mechanisms of the self-help technique and to enable comparisons to the working mechanisms in computer-based ABM. Lastly, data collection was conducted using self-report instruments. Future studies should investigate the efficacy of imaginal retraining for smokers using expert rating scales or implicit measures.

Conclusion

This was the first study to assess long-term effects of imaginal retraining. We found preliminary evidence that the novel self-help technique may lead to reduction in craving even 1 year after initial use. No changes in smoking behaviour were found, emphasizing the importance of a multimodal treatment approach that targets a variety of the maintaining factors of smoking behaviour. However, our findings are limited by participants' low use of the intervention and by the post hoc group allocation. Future studies need to investigate the long-term efficacy of imaginal retraining in RCTs that test alternative ways of conveying the technique to improve compliance.

Statement of Ethics

Both the initial and the follow-up study were approved by the Local Ethics Committee for psychologists at the University Hospital Hamburg-Eppendorf, Germany (LPEK-0023, LPEK-0104), and conducted in accordance with the World Medical Association Declaration of Helsinki. Participation in the follow-up trial was voluntary, and all participants gave electronic informed consent.

Conflict of Interest Statement

J.G. received research grants from the German statutory accident insurance (DGUV) and was employed in a research project funded by the European Union (ERC-2016-StG-Self-Control-677804) at the time of the study. S.M. received research grants from the DGUV and the German social organization *Aktion Mensch*. T.L. received funding from the Arctic University of Norway as a PhD student. A.G. has no conflict of interest to declare. S.K. received funding from the European Union (ERC-2016-StG-Self-Control-677804), the Max Planck Society, the German Science Foundation (TRR 169/C8, SFB 936/C7), and the Jacobs Foundation. The imaginal retraining technique was developed by S.M. and S.K.

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Author Contributions

J.G. substantially contributed to the conception of the study, participant acquisition, data analysis and interpretation, and drafting of the manuscript. A.G. substantially contributed to participant acquisition and revised the manuscript critically. S.M. substantially contributed to the conception of the study, the intervention, and participant acquisition and made substantial changes to the manuscript. T.L. substantially contributed to data analysis and interpretation and revised the manuscript critically. S.K. substantially contributed to the conception of the study and the intervention and revised the manuscript critically. All authors approved the final version of the manuscript to be published and agreed to be accountable for all aspects of the work.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

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