Preventing recurrence of depression: Long-term effects of a randomized controlled trial on cognitive control training for remitted depressed patients

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Abstract

Previous studies suggest that cognitive control training (CCT) shows potential as a preventive intervention for depression. This study is the first to examine long-term preventative effects of CCT, examining effects on: (a) task-specific cognitive transfer at one year follow-up; (b) recurrence of depression; and (c) functioning over the course of a year. 92 remitted depressed patients were randomized to a CCT or active control (ACT) condition. Effects of training were monitored using weekly assessments of emotion regulation, cognitive complaints, depressive symptomatology, and resilience (brief weekly questionnaire). At one year follow-up, participants completed a structured clinical interview, cognitive transfer task, and questionnaires. We observed task-specific cognitive transfer ($p < .001$, $d = 1.23$) and lower recurrence rates in the CCT condition ($p = .04$; Odds Ratio = 0.38). However, no long-term beneficial effects of training were observed on the weekly ratings of functioning, nor did groups differ in performance on the self-report questionnaires at one year follow-up.

Trial Registration: Open Science Framework: osf.io/g2k4w

Keywords: cognitive control, cognitive training, depression, remission, prevention

Depression is one of the world's most debilitating disorders, affecting millions of people worldwide. On top of the major impact on the patients' well-being, it is also associated with high societal costs (Ekman, Granström, Omérov, Jacob, & Landén, 2013; Kessler, 2012). Depression is often chronic of nature: the risk of recurrence following treatment is estimated to be between 40 and 60% (Bockting, Hollon, Jarrett, Kuyken, & Dobson, 2015). Crucially, relapse rates remain high despite treatment and are gradually increasing with increasing number of previous episodes (Bockting, Koeter, & Schene, 2010; Bockting et al., 2015; Bockting, Spinhoven, Koeter, Wouters, & Schene, 2006). Investigating innovative techniques that can reduce risk for recurrence is therefore of high priority. Provided the well-documented presence of cognitive impairments after remission (e.g., Levens & Gotlib, 2015) that influence psychosocial functioning (Weightman, Knight, & Baune, 2019), one such innovative technique is *cognitive control training* (CCT).

CCT refers to the use of computerized tasks to remediate executive functions, allowing flexible adaptation of one's thoughts and behavior as a function of one's goals (Braver, Cohen, & Barch, 2002; Cohen, 2017; Miller & Cohen, 2001). This may be of particular interest to patients following remission of depression, given the importance of cognitive control for daily functioning. In particular, cognitive control deficits have repeatedly been linked to impaired emotion regulation processes (for reviews, see Joormann & D'Avanzato, 2010; Joormann & Vanderlind, 2014; Mor & Daches, 2015), reflecting an increased cognitive and neurobiological vulnerability for recurrence of depression (De Raedt & Koster, 2010).

Among the various tasks that can be used to train cognitive control in the context of depression, a significant amount of the evidence stems from the adaptive Paced Auditory Serial Addition Task (aPASAT: Siegle, Ghinassi, & Thase, 2007; for a review, see Koster, Hoorelbeke, Onraedt, Owens, & Derakshan, 2017). On a neurobiological level it has been

suggested that, in order to successfully perform the PASAT, one needs to recruit the dorsolateral prefrontal cortex (DLPFC) while downplaying limbic interference (e.g., due to the challenging nature of the task; Siegle et al., 2007). Given the importance of these regions for successful regulation of emotions (e.g., De Raedt et al., 2010; Buhle et al., 2014), experimental manipulation of cognitive control may beneficially impact emotion regulation (e.g., fostering disengagement from irrelevant repetitive negative thoughts, allowing to override habitual ruminative response tendencies; Watkins & Roberts, 2020), and in turn decrease the likelihood of ending up in a state of sustained negative affect (De Raedt & Koster, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Koster et al., 2017; Watkins & Roberts, 2020).

Indeed, initial neuroimaging studies suggest that CCT may increase connectivity between prefrontal and limbic regions (Cohen et al., 2016), decreasing disruptions at the level of the DLPFC and amygdala (Cohen et al., 2016; Siegle et al., 2007). On a behavioral level, aPASAT training has shown to beneficially impact rumination (Siegle et al., 2007, 2014; Vanderhasselt et al., 2015) and depressive symptomatology (Brunoni et al., 2014; Siegle et al., 2007) in patients suffering from major depressive disorder (MDD). Moreover, findings from a recent double-blind randomized controlled trial (RCT) study suggest that CCT shows potential as a preventive intervention following remission from depression. That is, in a remitted depressed (RMD) sample it was found that ten sessions of the aPASAT results in a decrease in depressive symptomatology, less use of maladaptive emotion regulation strategies (such as depressive rumination), and improved resilience (Hoorelbeke & Koster, 2017). Compared to an active control condition, these effects were most pronounced at three months follow-up. Moreover, initial gains in cognitive control predicted lower depressive symptomatology at three months follow-up. Interestingly, this relation was partially mediated by immediate improvements in emotion regulation following CCT (Hoorelbeke & Koster, 2017).

Furthermore, earlier work with undergraduate students scoring high on trait rumination also suggests that aPASAT training may affect stress reactivity and depressive rumination (Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015). In addition, the immediate effects of aPASAT training have been investigated in daily life using experience sampling methodology, suggesting effects on emotion regulation in response to daily life stressors in a convenience sample (Hoorelbeke, Koster, Demeyer, Loeys, & Vanderhasselt, 2016) and RMD patients (Hoorelbeke et al., under review). These findings suggest that the aPASAT may buffer against use of rumination, possibly due to a more efficient use of working memory and attentional processes, which might in turn allow for more successful down-regulation of negative thoughts (Van den Bergh, Hoorelbeke, De Raedt, & Koster, 2018).

Indeed, a recent systematic review (Koster et al., 2017) and meta-analysis (Motter et al., 2016) suggest that cognitive training has added value in the context of depression. However, several key questions remain to be addressed. For instance, prior clinical studies have typically evaluated short-term cognitive and emotional transfer effects of CCT. Interestingly, several studies suggest that cognitive training procedures may have a long lasting impact on cognitive functioning (e.g., Schmiedek, Lovden & Lindenberger, 2014; Wilkinson & Yang, 2016). However, in the context of depression, repeated assessments of cognitive functioning following aPASAT training have typically been limited in time, exploring cognitive transfer immediately following training (Hoorelbeke et al., 2015, 2016; Siegle et al., 2007), at three- (Hoorelbeke & Koster, 2017), or six months follow-up (Vervaeke, Hoorelbeke, Baeken, & Koster, under review).

Related to this, assessments of effects of aPASAT training on emotional functioning have typically also been limited in time (e.g., Hoorelbeke & Koster, 2017; Vervaeke et al., under review), only providing indirect evidence for the potential of CCT as a preventive

intervention for depression (for a review, see Koster et al., 2017). Crucially, the value of CCT in terms of preventing recurrence of depression remains to be tested. Hence, we conducted an RCT to address these questions, exploring long-term effects of aPASAT training in RMD patients using a multi-method approach.

For this purpose, following an experimental manipulation of cognitive control (10 sessions of CCT vs. ACT) and evaluation of immediate effects of CCT on emotion regulation dynamics using an experience sampling procedure of which the results are reported elsewhere (Hoorelbeke et al., under review), participants were instructed to fill out a weekly questionnaire over a period of one year. This brief questionnaire contained indicators of severity of depressive symptoms, cognitive complaints, occurrence of stressful experiences, and indicators of emotion regulation over the past week. In addition, at one year follow-up, participants were re-invited to the lab where cognitive- and emotional functioning was re-assessed. At that time, using a structured clinical interview, we assessed recurrence of depressive episodes during the one year follow-up period. We aimed to:

- (1) Establish whether training related gains on a closely related cognitive control task would be observed at one year follow-up. For this purpose, we re-assessed a non-adaptive version of the PASAT task (i.e., the standardized PASAT task in which task difficulty is not tailored to the performance of the individual; Gronwall, 1977) as an indicator of task-specific transfer;
- (2) Evaluate effects of CCT in terms of prevention of recurrence of depression at one year follow-up;
- (3) Evaluate long-term effects of CCT on self-reported rumination, positive appraisal, cognitive complaints, depressive symptomatology, and resilience. For this purpose, these variables were assessed over the course of a year using a brief weekly

questionnaire, in addition to standardized questionnaires at baseline and one year follow-up.

Methods

Design

This manuscript reports the findings of a single-blind randomized controlled trial that was pre-registered (osf.io/g2k4w). The study was approved by the local ethics committee and written informed consent was obtained for all participants. This trial consisted of: (a) a screening phase, (b) baseline clinical assessment, (c) cognitive training procedure (experimental manipulation), during which (d) immediate effects were assessed in daily life over a period of four weeks using experience sampling methodology, (e) weekly monitoring of functioning over a period of one year using a brief questionnaire that was administered using participants' smartphones, and (f) a follow-up assessment including the non-adaptive PASAT, questionnaires, and a clinical interview to re-assess the state of (stable) remission at one year follow-up. The current manuscript reports on the long-term effects of CCT, including the weekly assessments over a period of one year (weekly questionnaire) and the follow-up assessment one year following training. Results pertaining the immediate effects of training in daily life (the experience sampling phase) are reported elsewhere (Hoorelbeke et al., under review).¹ Participants were randomized to the experimental condition following the pre-screening phase using RandList software (randomisation.eu). Participants were blind to the experimental condition. In addition, for evaluation of effects of CCT on recurrence of depression, we used independent raters to assess the inter-rater reliability for the clinical interviews (cf. *infra*). The latter were also blind to the training condition of participants.

Participants

RMD patients were recruited via advertisements in local newspapers and on social media. The study was conducted at the Faculty of Psychology and Educational Sciences of Ghent University. Participants were considered eligible for participation to the study if they: (a) were aged 23–65, (b) reported a history of depression, (c) possessed a smartphone with a data plan, and (d) did not meet criteria for an ongoing depressive episode, nor reported current substance abuse or presence of a psychotic disorder. Eligibility was assessed using a two-step screening protocol. Potential eligible participants first completed a brief telephone screening, using the relevant modules of the Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998; Van Vliet & De Beurs, 2007). This is a structured clinical interview based on the Diagnostic and Statistical Manual of Mental Disorders (DSM). Eligible participants were invited to Ghent University for a second screening using the Mood Disorders module of the MINI, which was administered by a licensed clinical psychologist, to (re-)establish a lifetime history of depression and current remission. Based on power analyses reported in prior preventative CCT studies (Hoorelbeke & Koster, 2017), we aimed to include 68 RMD patients in the analysis of short- and long-term effects of CCT. For this purpose, we oversampled because we expected significant drop-out due to the initial phase of intensive daily monitoring, the experimental manipulation, and the one year follow-up period. Participants enrolled in the study between March and July 2017.

Materials

Experimental manipulation.

The experimental manipulation was identical to the procedure set-out by Hoorelbeke and Koster (2017). Participants were randomized over two conditions, the CCT condition (experimental group) or a closely matched active control condition. In the CCT condition, participants performed the aPASAT task. During the aPASAT, participants were presented with

a continuous stream of auditory digits ranging from 1 to 9. Participants were instructed to continuously respond to the sum of the last two heard digits. Responses were made by clicking on the corresponding number in a fixed grid, with responses ranging from 2 to 18. In order to train cognitive functioning, the pace of the task was adapted based on the performance of the participant. That is, each session started with an intertrial interval (ITI) of 3000 ms. Every four consecutive correct / incorrect responses, this increased / decreased by 100 ms, providing a stressful training context. During the aPASAT, participants need to recruit the DLPFC while downplaying limbic interference (Siegle et al., 2007). That is, this task loads heavily on working memory functioning, where it is assumed to train the ability to select goal-relevant information and responses in the presence of task-irrelevant information (i.e., distractors). As such, this task is assumed to train central cognitive control features such as updating and interference control / inhibition (Van den Bergh et al., 2018).

Participants in the active control condition (ACT) performed a low cognitive load version of the aPASAT. That is, participants in the ACT group were presented with digits ranging from 1 to 18 and instructed to continuously click on the last heard digit (cf. Hoorelbeke et al., 2016). In line with the aPASAT task, the ITI decreased / increased with 100 ms following every four correct / incorrect responses. As such, participants in the ACT condition performed a speed of response training. This task was designed to draw less heavily on working memory processes than the aPASAT, while keeping all other characteristics similar to the experimental condition. This allows to control for motivational effects of cognitive training as well as effects of broader attentional processes that are likely to be trained in both conditions (e.g., sustained attention). Comparison between both conditions thus allows to evaluate effects of the working memory component of cognitive control.

In both training conditions, participants were instructed to complete 10 online sessions of the corresponding cognitive training task using the Millisecond software web application. Each session contained 400 trials. In order to foster task engagement (Siegle et al., 2014), both groups received standardized psycho-education regarding the cognitive training procedure (Hoorelbeke, Faelens, Behiels, & Koster, 2015).

Screening- and outcome measures.

Structured clinical interview. History of depression and recurrence of depression during the follow-up period were evaluated based on the criteria of the DSM-5 (American Psychiatric Association, 2013). In particular, we used the Dutch translation of the MINI (cf. supra; Sheehan et al., 1998; Van Vliet & De Beurs, 2007) during the screening phase to assess eligibility of participants for participation to the study. The Dutch version of this measure was developed based on an earlier version of the DSM (DSM-IV). As such, prior to this study each relevant item of the Dutch version of the MINI was carefully checked for compliance with the DSM-5 criteria for mood disorders (American Psychiatric Association, 2013), and adjusted where necessary to keep wording between the items of the MINI and the novel criteria of the DSM-5 consistent.

Moreover, state of remission was re-assessed at one year follow-up using the mood disorders module of the MINI. In particular, based on the DSM-5 criteria for depression, we evaluated *recurrence of depression* during the period of one year follow-up. The interviews were conducted by the first two authors of the manuscript, who also provided technical assistance to participants during the training phase and as such were not blind to the condition of participants. In order to prevent potential bias, and to be able to evaluate the quality of the assessments, all interviews were recorded and re-assessed by two independent raters who were blind to the experimental condition. Each independent rater rated approximately 50% of the

recorded interviews. This was conducted in a separate room, where the audio recordings were provided to the independent raters without further communication regarding the interviews between the researchers involved in this project and the independent raters during this stage of the project. In total, all interviews were rated twice. In case of disagreement between the independent raters and the researchers, we would follow the categorization of recurrence made by the independent rater.

Inter-rater agreement between the researchers and independent raters was perfect ($\kappa = 1.00$; Orwin & Vevea, 2009). For each of the participants completing the follow-up assessment, the researchers (i.e., the first two authors of this manuscript) and independent raters agreed in terms of diagnosis of absence or recurrence of depression. In addition, one participant was lost during the phase of follow-up due to suicide and as such did not complete the interview. Both the independent raters and researchers each independently categorized this as indicative for ‘recurrence of depression’.

Questionnaires. Following questionnaires were administered at baseline and at follow-up: (1) *Residual depressive symptomatology* was assessed using the 21-item Beck Depression Inventory (BDI-II-NL, range: 0 – 63; Beck, Steer, & Brown, 1996; Van der Does, 2002) and the Remission of Depression Questionnaire (RDQ, 41 items, range: 0 – 82; Peeters, Nicolson, Wichers, & Hacker, 2013; Zimmerman et al., 2013); (2) *Positive and Negative Affect* was assessed using the 20-item trait version of the Positive and Negative Affect Scales (PANAS; Engelen, De Peuter, Victoir, Van Diest, & Van den Bergh, 2006; Watson, Clark, & Tellegen, 1988), with a range of 10 – 50 for both positive- and negative affect; (3) *(Mal)Adaptive emotion regulation* was assessed using the Ruminative Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991; Treynor, Gonzalez, & Nolen-Hoeksema, 2003) and the Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski, Kraaij, & Spinhoven, 2001). In particular, we

used the total score of the RRS (22 items, range: 22 – 88; Treynor et al., 2003) and computed a compound score for use of adaptive (20 items, range: 20 – 100) and maladaptive emotion regulation strategies (16 items, range: 16 – 80) using the CERQ; (4) We used the Global Executive scale of the Behavior Rating Inventory of Executive Function Adult Version (BRIEF-A, 75 items, range: 70 – 210; Scholte & Noens, 2011) as an indicator of *cognitive complaints*; (5) *Resilience* was assessed using the Resilience Scale (RS, 25 items, range: 25 – 100; Portzky, 2008; Wagnild & Young, 1993); (6) In order to be able to control for *motivational effects*, the Credibility/Expectancy Questionnaire (CEQ, 6 items; Devilly & Borkovec, 2000) was also included at baseline and at one year follow-up. In addition, at follow-up participants filled out an item assessing whether they had the feeling that they were randomized to a placebo condition (placebo: yes / no; cf. Hoorelbeke & Koster, 2017); (7) Furthermore, at one year follow-up, participants completed several items pertaining the *need for treatment* during the past year. Two items assessed potential changes in experienced need for pharmacological or psychotherapeutic treatment for depression. In particular, participants indicated whether their use of psychotherapy / medication remained stable, increased, or decreased over the past year. In addition, participants reported number of psychotherapeutic consults and days administered to a (psychiatric) hospital due to depression over the past year. (8) Finally, participants also completed the List of Threatening Experiences (LTE, range: 0 – 13; Brugha & Cragg, 1990; Rosmalen, Bos, & De Jonge, 2012), allowing us to take into account the occurrence of *life events* during the follow-up phase. For the BDI-II-NL, RDQ, PANAS Negative Affect scale, RRS, CERQ compound score for maladaptive emotion regulation, BRIEF-A, and LTE, a high score is indicative of more psychopathological/maladaptive processes. In contrast, for the PANAS Positive Affect scale, the CERQ compound score for adaptive emotion regulation, the RS and the CEQ, a high score is indicative for more adaptive processes.

Weekly questionnaire. We developed a brief questionnaire to monitor effects of the experimental manipulation on functioning over a period of one year follow-up. For this purpose, seven items were re-assessed on a weekly basis using participants' own smartphones. On a fixed day of the week, participants would receive a text message (sent using SurveySignal software; Hofmann & Patel, 2015) containing a unique link directing them to an online Limesurvey questionnaire.

The online questionnaire contained seven items. With respect to the past week, participants were instructed to rate the extent to which: (a) the most influential event(s) that occurred were *unpleasant* rather than *pleasant events* ('Think about the most influential event you experienced over the past week. How (un)pleasant was this?', 1 = very unpleasant, 100 = very pleasant); (b) participants engaged in repetitive negative thinking regarding their feelings or problems, as an indicator of *depressive rumination* ('Focused on feelings', 'Focused on problems'; Moberly & Watkins, 2008); (c) participants deployed *positive appraisal*, cognitively (re)appraising events in a positive manner ('Focused on a positive meaning'); The three emotion regulation items presented in the current manuscript have been used in previous studies to model effects of CCT on emotion regulation dynamics in daily life in a convenience sample (Hoorelbeke et al., 2016). The two rumination items were developed by Moberly and Watkins (2008) to measure ruminative self-focus in a way that is consistent with the Response Styles Theory (Nolen-Hoeksema & Morrow, 1991; Moberly & Watkins, 2008). The positive appraisal item was proposed by Hoorelbeke et al. (2016) as an adaptive counterpart, aiming to assess positive appraisal as an important adaptive emotion regulation strategy in the context of depression vulnerability. (d) In addition, participants rated the extent to which they 'felt resilient' as an indicator of *resilience*. In line with the operationalization of resilience in the Resilience Scale (the perceived ability to cope with adversity, including aspects such as inner

strength and optimism; Wagnild & Young, 1993; Wagnild, 2009), the resilience item was defined as the extent to which participants considered themselves able to effectively cope with adversity in daily life; (e) Participants also rated the extent to which they experienced cognitive complaints ('Experienced cognitive complaints') or (f) depressive symptoms ('Experienced depressive symptoms'). *Depressive symptoms* referred to main depressive features based on the Diagnostic and Statistical Manual of Mental Disorders (e.g., being in a state of sustained negative affect, experiencing anhedonic features such as loss of interest), where – in line with the depression item proposed by Richmond et al. (2015) – we aimed to capture a wide spectrum of experiences relating to depression. *Cognitive complaints* referred to experienced working memory complaints or complaints related to broader executive functions such as attention deficits. These deficits typically remain present following remission of depression (Semkovska et al., 2019).

With the exception of occurrence of (un)pleasant events, all items were rated on a scale from 1 ("not at all") to 100 ("very much"). Each assessment started with the item measuring the occurrence of stressful/pleasant events, after which all other items were administered in a random order (to prevent order effects and sustain motivation to complete the repeated assessments).

To familiarize participants with the items of the weekly assessment, these items were assessed for the first time during the baseline lab visit after receiving written and oral instructions regarding the content of the items. The weekly online assessments started four weeks following the baseline assessment, allowing participants to complete the experimental manipulation. The assessments continued on a weekly basis for a period of one year following the experimental manipulation and ended during the follow-up visit. At that point, the items were re-assessed for the last time. The day of the week at which the text message was sent

varied across participants and was determined by the initial date of the baseline assessment. Signals were always sent at 6 PM. Participants were requested to complete the questionnaire within 24 hours upon receiving the first signal. If participants did not complete the questionnaire within one hour, a reminder signal was sent. After 24 hours, the link timed out and participants could no longer respond to the questionnaire.

Analysis of the associations between responses on the measures used in the brief weekly questionnaire to assess emotion regulation, cognitive complaints, depressive symptomatology and resilience, and the corresponding standardized self-report measures, provides support for the validity of the brief weekly questionnaire. In addition, the test-retest reliability and internal consistency of the items were adequate. For a more detailed discussion of the psychometric properties of the brief weekly questionnaire, please see supplemental material.

Task-specific cognitive transfer. In line with Hoorelbeke and Koster (2017), we relied on the non-adaptive PASAT task (Gronwall, 1977) to assess task-specific cognitive transfer. The non-adaptive or “standardized” PASAT task has been used to assess executive functioning in a multitude of clinical conditions among which traumatic brain injury, psychosis, and mood disorders (for a review, see Tombaugh, 2006). This task differs from the training task in that it forms an assessment task. That is, in contrast to the training task in which task difficulty is continuously modified based on one’s response (i.e., the aPASAT), the *non-adaptive* PASAT relies on ITIs that are fixed within blocks to assess executive functioning. Specifically, following a practice phase consisting of 10 trials, participants completed three blocks with increasing difficulty using an ITI of 3000 ms, 2000 ms, and 1500 ms respectively. Each block contained 60 trials, resulting in a total of 180 trials. The non-adaptive PASAT task was administered at baseline and at one year follow-up using the INQUISIT Millisecond software package.

Procedure

Following the two-phased screening procedure (which included a structured clinical interview), eligible RMD participants provided informed consent and completed a baseline assessment. This contained multiple questionnaires, a behavioral measure for cognitive control (non-adaptive PASAT) and psycho-education regarding the weekly questionnaire assessments, the cognitive training procedure and its rationale. At the end of the baseline assessment, participants' smartphones were registered in SurveySignal. In the period of four weeks following the baseline assessment, participants completed the online training procedure and were intensively monitored using experience sampling methodology (ESM). Following training, participants entered a follow-up phase during which functioning was repeatedly assessed on a weekly basis over a period of one year using a brief online questionnaire. At one year follow-up, participants were re-invited to the lab for a follow-up assessment of functioning. This included a re-assessment of the baseline questionnaire and the cognitive transfer task. Most importantly, at one year follow-up recurrence of depression was assessed using a structured clinical interview. At the end of this session, participants were debriefed and received financial reimbursement for participation to the study.

Results

Group Characteristics

Following the screening phase, 92 participants were randomized over the CCT and ACT condition (see Figure 1 for the CONSORT patient flow diagram). Both groups did not significantly differ prior to training concerning age ($t(87.35) = 0.04, p = .97$), gender ($\chi^2(1) = 0.87, p = .39$), indicators of socioeconomic status (education: $p = .20$; employment status: $p = .34$; Fisher's Exact tests), use of medication (all $ps > .27$, Fisher's Exact tests), history of depression (Number of previous episodes: $\chi^2(3) = 0.62, p = .92$; Mean episode length: $t(90) =$

0.49, $p = .63$; Time in remission: $t(90) = 0.28$, $p = .78$), or type of mood disorder (MDD vs. bipolar disorder: $p > .99$, Fisher's Exact test; for descriptive statistics, see Table 1). In addition, no significant group differences emerged at the level of the baseline questionnaires or performance on the cognitive transfer task (Table 2; all t s < 1.81).

Participant Blinding

We conducted two 2 (Time: Baseline vs. Follow-up) x 2 (Group: CCT vs. ACT) Mixed ANOVA's to test for motivational effects of undergoing the experimental manipulation. In line with our expectations, no significant interaction effects were found for credibility and expectancy of the intervention (cf. CEQ; Table 3; for descriptives, see Table 2). In addition, only a limited number of participants reported perceiving the intervention as being a placebo (ratio placebo : no placebo; CCT = 6 : 37; ACT = 9 : 30). Importantly, this proportion did not significantly differ between both groups ($\chi^2 = 1.14$, $p = .29$). Together, these findings suggest that blinding of participants was successful.

Research Question 1: Task-Specific Cognitive Transfer

Task-specific transfer effects were assessed using a non-adaptive version of the PASAT task that was administered at baseline and at one year follow-up. Using a 2 (Time: Baseline vs. Follow-up) x 2 (Group: CCT vs. ACT) Mixed ANOVA we observed a significant interaction for non-adaptive PASAT task performance (Table 3). Follow-up paired samples t -tests suggest that both groups showed a significant increase in cognitive task performance from baseline to one year follow-up (CCT: $t(42) = 13.88$, $p < .001$, 95% CI [0.23, 0.31], $d_{av} = 1.80$; ACT: $t(38) = 3.49$, $p = .001$, 95% CI [0.02, 0.08], $d_{av} = 0.28$). In absence of baseline group differences ($t(90) = 0.35$, $p = .73$, 95% CI [-0.08, 0.06], $d = 0.06$), participants in the CCT condition significantly outperformed participants in the ACT condition at one year follow-up ($t(68.30) = 5.29$, $p < .001$, 95% CI [0.12, 0.26], $d = 1.23$; for descriptives, see Table 2).

Research Question 2: Recurrence of Depression

Recurrence of depressive episodes was retrospectively assessed at one year follow-up using a structured clinical interview. One participant in the ACT condition was lost to follow-up due to suicide. This tragic event was categorized as ‘recurrence of depression’. As such, this analysis is based on $N = 40$ for ACT and $N = 43$ for CCT (cf. Figure 1). Overall, we observed high recurrence rates, with 36% ($N = 30$) of the participants meeting criteria for a depressive episode throughout the course of the follow-up period. Results from a Pearson Chi-Square test suggest a significant effect of training condition on recurrence of depression ($\chi^2 = 4.31$, $p = .04$, Cramér’s $V = .23$), demonstrating reduced recurrence of depressive episodes in the CCT condition (25.58%) compared to the ACT group (47.50%) (ratio recurrence : non-recurrence, CCT = 11 : 32, ACT = 19 : 21; Odds Ratio = 0.38). As such, the odds of recurrence of depression during one year follow-up were 2.63 times higher for participants in the ACT condition than for participants that were randomized to the CCT condition.²

In addition, at one year follow-up several indirect indicators of recurrence were assessed, among which self-reported need for pharmacological or psychotherapeutic treatment for depression, number of psychotherapeutic consults, and days administered to a (psychiatric) hospital due to depression over the past year (CCT: $N = 43$; ACT: $N = 39$). Training condition did not affect experienced need for pharmacological treatment for depression ($\chi^2 = 0.79$, $p = .68$, Cramér’s $V = .10$). That is, in both groups, most participants reported that use of pharmacological treatment for depression remained stable over the past year (CCT: 79%; ACT: 74%). A limited portion of participants reported a reduced (CCT: 5%; ACT: 3%) or increased need for pharmacological treatment over the past year (CCT: 16%; ACT: 23%). In contrast, a significant effect of training condition emerged at the level of reported need for psychotherapeutic treatment for depression ($\chi^2 = 7.35$, $p = .03$, Cramér’s $V = .30$). Specifically,

in the CCT group 35% of the participants reported a reduced need for treatment. 51% reported that need of psychotherapeutic treatment for depression remained stable over the past year. An additional 14% reported an increased need for treatment in the CCT condition. In contrast, only 13% of the ACT condition reported a reduced need for psychotherapy over the past year, whereas 79% and 8% of the ACT condition reported stable or increased need for psychotherapeutic treatment over the past year.

However, no significant group differences emerged at the level of consumption of health care services. For instance, using independent samples *t*-tests number of therapeutic consults used during the past year did not significantly differ between both conditions (CCT: $M = 6.47$, $SD = 9.52$; ACT: $M = 7.13$, $SD = 9.75$; $t(80) = 0.31$, $p = .76$, 95% CI [-4.90, 3.58], $d = 0.07$). Moreover, only one participant was hospitalized during the course of the follow-up period. As such, both groups did not significantly differ with regards to the amount of participants that were hospitalized due to recurrence of depression over the past year (ratio hospitalized : non-hospitalized, CCT = 0:43, ACT = 1:38; $p = .48$, Fisher's Exact Test). As such, although relatively more participants in the CCT group reported experiencing a decreased need for psychotherapy compared to the ACT condition, this was not reflected by lower actual use of healthcare services over the past year.

Research Question 3a: Weekly Ratings of Functioning

81 participants completed at least 50% of the weekly assessments over the period of one year follow-up and were included for these analyses (cf. Figure 1). The exact length of the weekly follow-up period was determined by the one year follow-up visit in the lab after which participation to the study terminated. This was situated between week 52 and week 60 following the baseline assessment ($Mdn = 55$). Given that the number of participants in each training condition rapidly declined after assessment week 52, we only included the first 52 weeks for

analysis of effects of CCT on weekly ratings of functioning at group level. Given the nature of the design, no weekly assessments took place between baseline and week four. This resulted in a maximum of 4050 unique assessments. Including the baseline assessment, participants completed 3670 assessments, with an average response percentage of 90.62%.

We used hierarchical linear modeling to examine effects of the experimental manipulation on rumination ($ICC = .60$), use of positive appraisal ($ICC = .58$), cognitive complaints ($ICC = .56$), depressive symptomatology ($ICC = .42$), and self-reported resilience ($ICC = .51$) over the course of one year. At level 1, we modeled how variation in the weekly assessments of the variable of interest was an effect of Time (number of weeks since baseline assessment), where we allowed to model linear and quadratic changes for each of the variables of interest over time. At the second level, we modeled the effect of training condition (CCT or ACT) on the slope of Time (linear) and Time² (quadratic), allowing random effects for the intercept and slope of Time and Time². We relied on an autoregressive AR(1) structure to account for the temporal correlation within an individual. Separate hierarchical linear models were fitted for each of the variables of interest. Results of the analyses are reported in Table 4.

In contrast to our hypotheses, no significant Time x Group interaction effects emerged for the variables of interest. Moreover, none of the main effects reached significance, with the exception of a significant linear and quadratic function for change in self-reported cognitive complaints over Time. That is, independent of the cognitive training procedure used (CCT or ACT), participants reported an initial decrease in cognitive complaints which remained fairly stable as time advanced (Supplemental Figure 1). In addition, we observed a tendency for an initial decrease in use of positive appraisal (Supplemental Figure 2). We observed no significant main or interaction effects for the weekly ratings of (un)pleasant events (Table 4).

Research Question 3b: Self-report Questionnaires at One Year Follow-up

Several questionnaires were administered at baseline and one year follow-up. Effects of training condition over time were assessed using 2 (Time: Baseline vs. Follow-up) x 2 (Group: CCT vs. ACT) Mixed ANOVA's. The results of these analyses are reported in Table 3 (for descriptives, see Table 2). Overall, in contrast to our hypotheses no significant Time x Group interaction effects were observed. For several indicators of emotion regulation, a main effect of Time was observed. Participants reported a decrease in rumination (RRS) and maladaptive emotion regulation in general (CERQ). Furthermore, participants reported an increase in resilience (RS) over time and a reduction in cognitive complaints (BRIEF). However, no differential effects of training condition emerged at one year follow-up.

In addition, participants were asked to report life events that had occurred over the past year using the LTE. Effects of an independent samples *t*-test suggest that both groups did not differ in terms of occurrence of life events (CCT: $M = 1.84$, $SD = 1.36$; ACT: $M = 1.82$, $SD = 1.35$; $t(80) = 0.06$, $p = .96$, 95% CI [-3.11, 3.15], $d < 0.01$).

Discussion

The aim of the current study was to examine the long-term effects of CCT for remitted depressed patients. In particular, we aimed to examine cognitive and emotional transfer effects over a period of one year follow-up. Based on prior work suggesting that task-specific transfer effects remain present until three months following training (Hoorelbeke & Koster, 2017), our first aim was to examine task-specific transfer at one year follow-up. In line with our hypothesis, participants in the CCT condition showed a large increase in cognitive task performance from baseline to one year follow-up, which significantly differed from the ACT condition.

Interestingly, at one year follow-up recurrence rates were found to be significantly lower in the CCT condition compared to the ACT group, suggesting that CCT may indeed be effective

as a preventative intervention for RMD patients. This finding is in line with previous studies suggesting that CCT may reduce depression vulnerability, as shown by previously observed short-term beneficial effects of aPASAT training in healthy- (e.g., Hoorelbeke et al., 2016), at-risk- (e.g., Calkins, McMorran, Siegle, & Otto, 2015; Hoorelbeke et al., 2015; Hoorelbeke & Koster, 2017) and clinically depressed patient samples (e.g., Brunoni et al., 2014; Segrave, Arnold, Hoy, & Fitzgerald, 2014; Siegle et al., 2007; Siegle et al., 2014; Vanderhasselt et al., 2015). Noteworthy, the obtained Odds Ratio (OR) of 0.38 corresponded to prior reported effects of widely used preventative interventions in the context of depression. For instance, in a meta-analysis comparing effects of antidepressant medication such as Venlafaxine in terms of prevention of recurrence of depression to a placebo intervention, Bauer, Tharmanathan, Volz, Moeller, and Freemantle (2009) reported an OR of 0.37 in favor of Venlafaxine. Similarly, Cox and colleagues (2012) reported an OR of 0.34 in a meta-analysis of effects of antidepressants on recurrence of depression in children and adolescents. Furthermore, the obtained effect of CCT on risk for recurrence of depression was of similar magnitude as prior reported preventative effects of Mindfulness Based Cognitive Therapy (MBCT). For instance, Teasdale and colleagues (2000) compared effects of MBCT + Treatment As Usual (TAU) with a TAU control group, showing beneficial effects of MBCT in terms of prevention of recurrence of depression which were moderated by amount of prior depressive episodes. However, when not taking into account the amount of prior depressive episodes in RMD patients, the overall observed OR for MBCT + TAU versus TAU was 0.57 (Teasdale et al., 2000), suggesting that risk for recurrence of depression was 1.75 times higher in the TAU group compared to the MBCT + TAU group respectively. In a follow-up study, Ma and Teasdale (2004) replicated the beneficial additive effects of MBCT to TAU in terms of prevention of recurrence of depression, resulting in an OR of similar magnitude (OR = 0.39). These findings highlight the clinical potential of CCT as a preventative intervention for remitted depressed patients. Compared to

existing preventative interventions for depression, one of the main advantages of CCT is that it can be easily disseminated online, offering the possibility to reach a large population in a cost effective manner. In addition, CCT lends itself to be integrated within existing treatment protocols and is less time consuming.

In addition to the observed beneficial effects in terms of reduced risk for recurrence of depression, participants in the CCT condition also reported having experienced a reduced need for psychotherapeutic treatment over the past year compared to the ACT condition. This may be indicative for increased feelings of agency in the CCT condition. However, both conditions did not significantly differ in terms of absolute number of psychotherapeutic consults, nor in occurrence of hospitalization due to (recurrence of) depression. In this context, it should be noted that number of psychotherapeutic consults include maintenance sessions, among which sessions aimed at monitoring the use of (antidepressant) medication. However, these findings may also suggest that CCT as a standalone intervention did not have a clinical significant impact on daily life functioning over the course of one year. Related to this, both groups did not differ in terms of estimated need for psychopharmacological treatment for depression, where most participants reported having experienced a stable need for use of (preventative) psychopharmacological treatment for depression. This is in line with previous findings (Siegle et al., 2014) suggesting no effects of CCT on amount of outpatient psychotherapeutic consults, nor on medication management visits. In the latter study, only an effect of CCT was found on number of intensive outpatient day-treatment visits (Siegle et al., 2014). Following up on this, it would be interesting for future studies to monitor quality of life, use of healthcare services, and related costs in a more rigid manner, not strictly relying on retrospective self-report measures. This would allow evaluation of the potential of CCT from a health economic perspective.

A third aim of the study was to model long-term effects of CCT on indicators of functioning. Although previous findings suggest that beneficial effects of CCT on indicators of vulnerability for depression may continue until three months following training (e.g., Hoorelbeke & Koster, 2017), no differential effects of training condition were found on self-report questionnaires for mood, emotion regulation, residual symptomatology, and resilience during the assessment of functioning at one year follow-up. Instead, both groups demonstrated a significant decrease in rumination, use of general maladaptive emotion regulation strategies, and cognitive complaints. Furthermore, we observed a significant increase in resilience over time in both groups. This may be due to overlap between the domains of influence of both training procedures (i.e., potentially impacting broader attentional processes). This is in line with a recent replication study providing mixed evidence for the emotional transfer effects of aPASAT training compared to a similar active control training in RMD patients (Vervaeke et al., under review). That is, in contrast to Hoorelbeke and Koster (2017), Vervaeke and colleagues (under review) did not observe beneficial effects of aPASAT training on self-reported emotion regulation or resilience over a period of six months follow-up. Instead, Vervaeke et al. (under review) observed a general reduction in rumination over time. Interestingly, Vervaeke et al. (under review) did, however, observe beneficial effects of aPASAT training on depressive symptomatology, which became apparent at three months follow-up and remained present until six months follow-up.

In order to shed further light on how emotional transfer effects of CCT develop over time, we monitored participants' functioning over a period of one year using weekly assessments of functioning. In particular, use of (mal)adaptive emotion regulation strategies, self-reported cognitive complaints, depressive symptomatology, and resilience were reassessed weekly over the period of one year follow-up. Here, we were interested in emotional transfer effects over time, given the high clinical value of such data (e.g., allowing to detect

when booster sessions may be needed). In line with previous studies with RMD patients (e.g., Weissman, Prusoff, & Klerman, 1978), the subjects included in the current study showed considerable fluctuations in residual symptomatology. However, using the weekly assessments of functioning, our analyses of impact of training on severity of residual symptomatology, emotion regulation, and resilience over the period of one year follow-up suggested no differential long-term effects of CCT. Instead, both groups showed an initial decrease in cognitive complaints, which was maintained throughout the follow-up period. The lack of differential effects of CCT on the weekly ratings and standardized questionnaires that were reassessed at one year follow-up seems to be at odds with prior reported findings in the literature (for a recent review, see Koster et al., 2017), and the observed effect of CCT on risk for recurrence of depression.

Identifying which factors may have contributed to the observed discrepancy between the analyses pertaining effects of training condition on cognitive transfer, functioning throughout the course of a year and recurrence risk is challenging, given the vast differences between the methods that support these results. As such, several factors may have contributed to this. For instance, for the weekly ratings, participants were required to indicate to what extent they had experienced “depressive symptoms” in the past week on a scale ranging from 1 to 100 using a one-item question. This offers a more crude assessment of severity of depressive symptoms. During the structured clinical interview, in contrast, participants were asked in-depth whether *specific* depressive symptoms were or were not present most of the time, for at least two consecutive weeks, sometime in the past year. Related to this, a potential source of discrepancy is located at the level of data-analysis. That is, our analyses of functioning over the course of a year aimed to model increases or decreases at group level in symptomatology over time. Consequently, this does not take into account the temporary chunking of elevated depressive symptoms over time at an individual level, which is key to the diagnosis of

recurrence of depression (cf. the two-week criteria). As such, in order to clarify the observed discrepancies between findings stemming from analysis of the weekly ratings of depressive symptomatology and the diagnosis of recurrence of depression at one year follow-up, an alternative data-analytical approach than the approach that was pre-registered is necessary. For this purpose, in a post-hoc fashion we conducted survival analyses on the weekly data, using the Area Under the Curve indicator to statistically inform us of the ideal cut-off value for 'recurrence of depression' based on the weekly ratings (taking into account temporal chunking of the data to meet the two-week criteria). Results of these analyses are presented as supplemental material. In line with the statement that CCT may have beneficial effects on (risk for) recurrence of depression, we observed a tendency for both survival distributions to differ (cf. supplemental material). In particular, a discrepancy between the CCT and ACT condition seemed to develop around the period of three months following the intervention. This is in line with recent findings suggesting a delayed effect of CCT on depressive symptomatology in RMD patients (e.g., Vervaeke et al., under review). Interestingly, based on the obtained cut-off for the weekly ratings, estimated recurrence rates were 31.82% in the CCT condition versus 51.22% in the ACT condition. This resembles the recurrence rates based on the structured clinical interview at one year follow-up (CCT: 25.58%; ACT: 47.50%). Although these findings suggest that CCT may impact risk for recurrence of depression, it is important to note that the findings stemming from the standardized questionnaires suggest that this did not result in reduced severity of (residual) depressive complaints in the CCT condition at one year follow-up.

Our results also suggest that RMD patients show substantial fluctuations in self-reported emotion regulation and depressive symptomatology. These findings may account for inconsistencies within the CCT literature. That is, although multiple studies suggest the potential of CCT in reducing depression vulnerability (e.g., Brunoni et al., 2014; Calkins et al.,

2015; Martin et al., 2018; Segrave et al., 2014; Siegle et al., 2007; Siegle et al., 2014; Vanderhasselt et al., 2015), it should be noted that several studies have failed to identify short-term emotional transfer effects following aPASAT training or other CCT procedures. For instance, comparing effects of CCT versus an active control training in participants with an euthymic or depressed mood, Moshier, Molokotos, Stein, and Otto (2015) observed no beneficial effects of aPASAT and Wells' attention training on depressive symptomatology. Similarly, Wanmaker, Geraerts, and Franken (2015) observed no emotional transfer effects following an intensive combined adaptive dual n-back and symmetry span training in patients with MDD and/or anxiety. Moreover, in a recent study in which Moshier and Otto (2017) evaluated the efficacy of aPASAT and Wells' attention training as an add-on intervention for behavioral activation in MDD patients, no beneficial effects of adjunctive CCT were observed. In this context, it should be noted that previous studies have typically relied on one or two post-training assessments to evaluate effects of CCT (e.g., Hoorelbeke & Koster, 2017). However, our findings indicate the importance of using multiple assessments when evaluating effects of interventions in clinical samples.

Furthermore, as to date we have limited knowledge regarding the mechanisms underlying previously reported beneficial effects of CCT, suggesting a strong need for mechanistic research exploring how cognitive control is causally related to risk for depression. In this context, exploring how variability in training task progress, cognitive gains, and emotional transfer relate, may provide a first step forward. For instance, exploratory analyses suggest that within the CCT condition, training task progress was related to cognitive transfer. However, training task progress was unrelated to change in the weekly ratings of functioning over the one year follow-up period, or change in the self-report measures from baseline to one year follow-up. Interestingly, in line with our main analyses suggesting beneficial effects of CCT on cognitive task performance and risk for recurrence of depression, cognitive transfer

emerged as a marginal significant predictor for recurrence of depression (for a more detailed discussion of these findings, see supplemental material).

To the best of our knowledge, this pre-registered study is the first to directly examine beneficial effects of CCT on recurrence of depression. A major strength of this study is the intensive multi-method procedure used to assess effects of CCT, and the relatively long follow-up period, allowing to gain a better understanding of how effects of CCT develop over time. This offers an important advantage given that previous studies have typically explored short-term effects of CCT using a limited amount of assessments. In line with our hypotheses, our findings suggest that task-specific transfer effects remain present until at least one year following the experimental manipulation. Importantly, we observed a significant effect of training condition, suggesting a reduced risk for recurrence of depression in the CCT condition compared to the active control condition. This effect was of comparable strength of widely accepted preventative interventions for depression. However, the beneficial effect of CCT on recurrence of depression was at least partially inconsistent with our indicators of functioning (cf. questionnaire data). Overall, this suggests that the long-term benefits of CCT may be limited, where future research is necessary to identify under which conditions CCT may yield emotional transfer effects and whether booster sessions are necessary to maintain treatment gains.

Some limitations need to be mentioned with regard to the discrepancies between the different outcome measures. First, in line with previous clinical studies in which the aPASAT was used to train cognitive control (e.g., Hoorelbeke & Koster, 2017; Siegle et al., 2007), cognitive transfer was assessed using a cognitive task that showed high resemblance to the training procedure. Although this allows to evaluate task-specific cognitive transfer, no conclusions can be drawn regarding more distal cognitive transfer effects. That is, effects may

be task specific or impacted by confounds (e.g., due to strategy learning; Shipstead, Redick, & Engle, 2012). Here, it would be interesting for future studies to provide an in-depth exploration of cognitive transfer effects following aPASAT training, relying on a multitude of behavioral measures.

Related to this, a second limitation of this study is that task-specific cognitive transfer effects were only assessed at one year follow-up. Similarly, the standardized self-report questionnaires and the structured clinical interview were only re-assessed at one year follow-up, although our brief questionnaire / mobile assessments allowed to continuously model effects of CCT from baseline until one year follow-up. Absence of a cognitive assessment immediately following training does not allow to evaluate the course of the task-specific cognitive transfer effects over the one year follow-up period. In this context, previous studies suggest a slight decrease in task-specific cognitive transfer over time following CCT in remitted depressed patients (e.g., comparing post-training performance with performance on the non-adaptive PASAT task at three months follow-up; Hoorelbeke & Koster, 2017). Taking this into account, the magnitude of the observed task-specific cognitive transfer effect at one year follow-up in the current study is noteworthy.

Third, we kept the amount of items in the weekly questionnaire at a minimum to foster compliance to the assessment procedure. Choice of items was based on previous studies in which positive effects of CCT were obtained (Hoorelbeke et al., 2016). Despite the fact that one-item solutions for depression have previously been validated against standardized questionnaires (Richmond et al., 2015), it is likely that our one-item measure for depression did not allow to represent the full complexity of depressive symptoms. Importantly, the items used in our brief weekly questionnaire show adequate reliability and validity (cf. supplemental material). However, using multiple items to assess the constructs of interest may yield a more

detailed understanding of training effects. For instance, using the recently validated measures for repetitive negative thinking (e.g., Rosenkranz, Takano, Watkins, & Ehring, 2019).

Fourth, the current study compared effects of CCT with an ACT condition in which an adaptive speed of response task was used. Although this allows to control for motivational effects of undergoing training, at the same time this forms a very strict control condition. That is, it is likely that broader executive functions (e.g., attentional processes) are also trained to some extent in the ACT condition, reducing the likelihood to detect differential training effects of CCT. In addition, the training procedure used in the current study relies on neutral stimuli, whereas it has been argued that CCT procedures using emotional stimuli may be more effective (e.g., Iacoviello et al., 2014; Schweizer, Hampshire, & Dalgleish, 2011; for a review, see Koster et al., 2017).

Fifth, recurrence of depression was assessed retrospectively at one year follow-up using a structured clinical interview. Related to this, we did not assess time to recurrence during this interview. We would suggest future studies to monitor recurrence continuously in daily life, allowing to take into account time until recurrence.

Sixth, in line with the pre-registration the main analyses presented in the current manuscript mostly rely on a nomothetic approach. However, given the strong heterogeneity observed in RMD patients, it would be informative for future studies to yield a ideographic approach (e.g., Bosley, Fisher, & Taylor, 2018; Fisher, Medaglia, & Jeronimus, 2018). Finally, although we used mixed methods to better understand the mechanisms of training effects, the current study failed to clarify why training yielded beneficial effects on some of the variables of interest but not on others. This may be considered a weakness, yet we feel that such data are crucial to better understand causal mechanisms of change where CCT did not influence some of the expected processes (e.g., rumination). Similar to the Cognitive Bias Modification field,

the CCT field may require additional tolerance for mixed findings, in order to advance (Koster & Bernstein, 2015).

Conclusion

Based on promising short-term effects of CCT in the literature, the current study set-out to examine long-term effects of CCT on indicators of cognitive and emotional transfer. For this purpose, participants were monitored using a brief weekly questionnaire over a period of one year following the training, which concluded with a follow-up assessment in the lab. At one year follow-up, task-specific cognitive transfer effects were observed, with the CCT condition showing a considerable increase in cognitive task performance compared to the ACT condition. Moreover, CCT was related to reduced recurrence of depressive episodes during the period of one year follow-up. This effect was of similar magnitude of prior findings reported in the literature stemming from widely accepted preventative interventions for depression. These findings suggest that CCT may indeed show clinical potential as a preventative intervention following remission from depression. However, no differential effects of training condition emerged for the self-report questionnaires at one year follow-up. Instead, we observed a general decrease in cognitive complaints, improvements in emotion regulation, and an increase in self-reported resilience for both the CCT and ACT condition. Moreover, CCT did not affect level of depressive symptomatology at one year follow-up. In addition, the weekly ratings of functioning in daily life did not suggest long-term beneficial effects of CCT. Together, these findings indicate that the emotional transfer effects of CCT should be interpreted with caution.

Footnotes

1. The data reported in this manuscript (MS1) relate to the long-term transfer effects of a randomized controlled trial on CCT for RMD patients. For this purpose, we modeled effects of training on task-specific cognitive transfer, recurrence of depression, and self-reported emotion regulation, residual symptomatology, and resilience over a period of one year follow-up. Immediate / Online effects of cognitive control training – i.e., the effects of the training procedure on a four-week experience sampling phase – are reported elsewhere (MS2; Hoorelbeke, Van den Bergh, De Raedt, Wichers, Albers, & Koster, under review). In addition, in line with the pre-registration, the first week of the experience sampling phase preceded the training phase and was used as a prospective dataset to replicate prior models on the role of resilience following remission of depression (MS3; Hoorelbeke, Van den Bergh, Wichers, & Koster, 2019).
2. The impact of training condition on risk for recurrence of depression remained present after controlling for baseline severity of residual symptomatology in a logistic regression model. That is, both predictors made a (marginal) significant contribution to the model (Group: $b = -0.94$, $W = 3.79$, $p = .05$; Baseline BDI-II: $b = 0.04$, $W = 2.93$, $p = .09$).

Declarations of interest

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Table 1*Group characteristics*

	Training condition	
	CCT (N=47)	ACT (N=45)
Mean age (<i>SD</i>)	45.74 (14.21)	45.84 (11.40)
Gender (male : female)	19 : 28	14 : 31
Highest degree obtained (No higher education : Bachelor : Master : PhD)	13 : 13 : 20 : 1	7 : 20 : 18 : 0
Employment (Full : Part-time : Unemployed : Retired : Incapacitated : Student)	17 : 11 : 3 : 6 : 6 : 4	16 : 17 : 2 : 4 : 6 : 0
Number of previous episodes (ratio RMDs reporting 1 : 2 : 3 : ≥ 4 episodes)	9 : 10 : 10 : 18	8 : 7 : 11 : 19
Mean self-reported episode length in months (<i>SD</i>)	7.27 (9.94)	6.36 (7.74)
Mean self-reported time since previous episode in months (<i>SD</i>)	31.80 (44.08)	29.29 (40.96)
% reporting depressive episodes within a bipolar disorder	6%	7%
% reporting current use of antidepressant medication	51%	49%
% reporting current use of benzodiazepines	13%	22%
% reporting current use of lithium	6%	4%
% reporting current use of antipsychotic or neuroleptic medication	2%	2%

Table 2*Descriptive information for cognitive task performance and self-report questionnaires per condition over time*

Variables	Training condition							
	CCT				ACT			
	Time 1 (N=47)		Time 2 (N=43)		Time 1 (N=45)		Time 2 (N=39)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Cognitive control (non-adaptive PASAT)	0.55	0.17	0.81	0.13	0.56	0.17	0.62	0.18
Depressive symptoms (BDI-II-NL)	11.28	8.58	9.51	8.75	13.07	9.66	11.38	10.16
Residual symptoms (RDQ)	22.40	16.49	20.37	15.45	24.87	14.38	23.38	17.60
Positive Affect (PANAS)	34.77	7.12	35.12	8.46	33.33	7.20	33.28	7.25
Negative Affect (PANAS)	23.15	6.70	23.30	7.43	25.42	6.07	23.67	6.96
Rumination (RRS)	49.96	12.57	45.95	14.44	53.98	12.83	48.90	13.30
Adaptive Emotion Regulation (CERQ)	65.23	13.27	67.51	14.46	61.33	16.73	64.41	16.33
Maladaptive Emotion Regulation (CERQ)	38.85	7.61	36.12	8.05	40.44	9.19	39.38	9.44
Resilience (RS)	73.06	11.64	75.53	12.69	74.42	11.13	76.49	11.58
Cognitive complaints (BRIEF-A)	123.70	20.22	118.91	22.85	131.33	20.25	125.13	25.21
Credibility (CEQ)	0.02	2.47	0.16	2.40	-0.02	2.27	-0.17	2.90
Expectancy (CEQ)	0.15	2.67	-0.04	2.80	-0.16	2.59	0.05	2.83

Table 3*Evidence for training effects from Mixed ANOVA's*

Variables	Main effect of Time				Main effect of Group				Time x Group interaction			
	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2
Cognitive control (non-adaptive PASAT)	168.53	1, 80	< .001	.68	5.51	1, 80	.021	.06	78.41	1, 80	< .001	.50
Credibility (CEQ)	0.06	1, 80	.80	<.01	0.06	1, 80	.82	<.01	0.39	1, 80	.54	<.01
Expectancy (CEQ)	<0.01	1, 80	.99	<.01	0.03	1, 80	.88	<.01	0.23	1, 80	.63	<.01
Depressive symptoms (BDI-II-NL)	1.49	1, 80	.23	.02	0.77	1, 80	.38	.01	0.10	1, 80	.75	<.01
Residual symptoms (RDQ)	0.88	1, 80	.35	.01	0.41	1, 80	.52	<.01	0.31	1, 80	.58	<.01
Positive Affect (PANAS)	0.18	1, 80	.68	<.01	0.96	1, 80	.33	.01	0.21	1, 80	.65	<.01
Negative Affect (PANAS)	1.37	1, 80	.25	.02	0.81	1, 80	.37	.01	1.44	1, 80	.23	.02
Rumination (RRS)	12.75	1, 80	.001	.14	1.87	1, 80	.18	.02	0.24	1, 80	.63	<.01
Adaptive Emotion Regulation (CERQ)	3.12	1, 80	.081	.04	0.71	1, 80	.40	.01	0.14	1, 80	.71	<.01
Maladaptive Emotion Regulation (CERQ)	5.13	1, 80	.026	.06	2.87	1, 80	.094	.04	0.34	1, 80	.56	<.01
Resilience (RS)	4.94	1, 80	.029	.06	0.30	1, 80	.58	<.01	0.18	1, 80	.67	<.01
Cognitive complaints (BRIEF-A)	7.49	1, 80	.008	.09	2.12	1, 80	.15	.03	0.03	1, 80	.86	<.01

Table 4*Evidence for training effects in daily life from Hierarchical Linear Modeling*

<i>Variables</i>	<i>Term</i>	γ	<i>SE</i>	<i>t</i>	
(Un)Pleasant events	Time	-0.203	0.213	-0.95	
	Time ²	0.003	0.004	0.80	
	Group	2.073	4.410	0.47	
	Time x Group	-0.071	0.297	-0.24	
	Time ² x Group	<0.001	0.005	0.03	
Rumination	Time	-0.123	0.188	-0.66	
	Time ²	0.003	0.003	0.82	
	Group	-6.214	4.307	-1.44	
	Time x Group	0.138	0.261	0.53	
	Time ² x Group	-0.003	0.005	-0.53	
Positive appraisal	Time	-0.270	0.158	-1.70	†
	Time ²	0.006	0.003	1.95	†
	Group	-0.868	4.610	-0.19	
	Time x Group	0.006	0.220	0.03	
	Time ² x Group	-0.001	0.004	-0.24	
Cognitive complaints	Time	-0.399	0.199	-2.00	*
	Time ²	0.007	0.004	2.05	*
	Group	-1.099	3.907	-0.28	
	Time x Group	0.108	0.277	0.39	
	Time ² x Group	-0.003	0.005	-0.61	
Depressive symptomatology	Time	0.248	0.201	1.24	
	Time ²	-0.004	0.004	-1.16	
	Group	0.348	3.684	0.09	

Resilience	Time x Group	-0.232	0.280	-0.83
	Time ² x Group	0.004	0.005	0.79
	Time	-0.026	0.142	-0.18
	Time ²	0.001	0.003	0.48
	Group	1.471	3.844	0.38
	Time x Group	-0.283	0.198	-1.43
	Time ² x Group	0.004	0.004	1.12

Note: † = $p < .10$, * = $p < .05$, ** = $p < .01$, *** = $p < .001$

Figure 1. CONSORT Flow diagram

Note: Participants who did not complete at least 50% of the weekly assessments or were lost to follow-up did not significantly differ from participants who were included for the analyses in terms

of level of baseline functioning or clinical characteristics. However, we did observe a tendency for participants who did not complete the weekly assessments to report lower levels of maladaptive emotion regulation at baseline (as measured using the CERQ; completers: $M = 40.20$, $SD = 8.41$; non-completers: $M = 35.45$, $SD = 7.46$; $t(90) = 1.78$, $p = .08$; all other $ps \geq .12$).