Computerised Memory Specificity Training (c-MeST) for Major Depression:

A Randomised Controlled Trial

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Abstract

Background: Given modest response and high relapse after treatment for Major Depressive Episodes (MDE), the development and refinement of treatments to target cognitive vulnerabilities is indicated. Memory Specificity Training (MeST) remediates deficits in recalling detailed memories of past experiences through repeated practice of autobiographical memory retrieval. This randomised controlled trial aimed to assess the efficacy of an online, computerised version of MeST (c-MeST) for MDE.

Methods: Adults ($N = 146$, 89.7% female) aged 18 and over (M age = 46.1, $SD = 13.3$) with a current MDE were randomised to the c-MeST program or wait-list control group. Primary outcomes were diagnostic status of MDE and self-reported depressive symptoms at baseline, post-training, one-month, and three-month follow-up. Memory specificity was assessed, as well as other variables thought to contribute to reduced memory specificity, such as rumination and cognitive avoidance.

Results: Significantly fewer participants in the c-MeST group, relative to control, met criteria for an MDE at one-month follow-up (35.7% c-MeST vs. 60.6% control), but not at other time-points. The c-MeST group scored significantly higher on memory specificity at all time-points following baseline ($d = 0.51 - 0.97$), and lower on depressive symptoms at one ($d = 0.53$) and three-month follow-up ($d = 0.67$). Changes in memory specificity mediated the effect of c-MeST on depressive symptoms at follow-up. Few differences were noted on secondary measures.

Conclusion: c-MeST can improve memory specificity and depressive symptoms in people with a MDE, and may speed the rate of recovery. Future studies can further examine the mechanisms through which this occurs.

Keywords: memory specificity; depression; major depressive episode; randomised controlled trial; overgeneral memory

Current evidence indicates that the effects of treatment for major depression are robust but modest (e.g., Cuijpers, Karyotaki, Reijnders, & Ebert, 2019; Warden et al., 2007) and many people either do not respond to first-line treatments or relapse (Sim et al., 2016; Steinert et al., 2014). In recent times, expert groups have highlighted that treatment effects could be improved by increasing understanding of specific cognitive processes underlying psychopathology, and targeting these cognitive processes more effectively (Holmes et al., 2018). Given the prevalence and burden of major depression worldwide (World Health Organization, 2019), there is clear need for the continued development and refinement of interventions that target known cognitive mechanisms for the alleviation of symptoms.

One reliable cognitive marker in depression is difficulties in recalling spatiotemporally located events from the past (Sumner, Griffith, & Mineka, 2010). Depressed individuals, relative to non-depressed, more often fail to recall memories of event-specific experiences that occurred within the space of a day; instead, they provide memories of experiences that extended over longer periods of time, categories of repeated events, or abstractions of various experiences. This impairment, termed overgeneral memory (OGM) or reduced autobiographical memory specificity (rAMS) is recognised as a factor involved in the onset and maintenance of clinical depression (Sumner et al., 2010). Further, rAMS appears to occur to effect both positively and negatively-valenced memories in depression (Liu, Li, Xiao, Yang, & Jian, 2013). The ability to recall contextualized information from past experiences is critical in adaptive functioning, and in processes such as problem-solving (Goddard, Dritschel, & Burton, 1996), social support (Barry et al., 2019; Chiu, Ma, Boddez, Raes, & Barry, 2019), and imagining and anticipating future events (Schacter, Addis, & Buckner, 2007). As a means of increasing memory specificity among those with depression, Memory Specificity Training (MeST; Raes, Williams, & Hermans, 2009) has been shown to be effective (Barry, Sze, Raes, 2019). In MeST, individuals engage in sustained practice recalling specific autobiographical memories in response to a series of cue words. Over a course of weekly sessions (typically 4-5) in a group-based format, facilitators prompt participants to self-generate specific memories to cue

words. They then provide feedback on whether these responses are specific or not and guide them to elaborate on details. An initial pilot trial of MeST with inpatients indicated an increase in memory specificity following four, weekly group-based sessions (Raes et al., 2009). A subsequent, randomised controlled trial again showed significant increases in memory specificity which mediated subsequent reductions in depressive symptoms (Neshat-Doost et al., 2013). An uncontrolled trial of MeST with a sample of depressed individuals on an outpatient wait-list also found significant increases in memory specificity and decreases in depressive symptoms (Eigenhuis et al., 2017). Finally, a recent cluster-randomised trial demonstrated that MeST lead to improvements in memory specificity and was equivalent with another validated intervention (psychoeducation and supportive counselling) in reducing depressive symptoms (Werner-Seidler et al., 2018). Overall, evidence indicates that the face-to-face (or off-line) MeST training program can produce significant improvements in AM specificity and reductions in depressive symptoms (Barry et al., 2019).

Given the straightforward nature of MeST, it represents a good candidate for adaptation to an online delivery format. Online interventions for depression can be clinically- (Karyotaki et al., 2018) and cost-effective (Donker et al., 2015). They are also more accessible and less resource-intensive, thereby being more easily scalable to reach a wider population. Accordingly, a fully computerized, automated version of the MeST training program (c-MeST) has been developed, and demonstrated efficacy in increasing memory specificity in a non-clinical sample (Takano, Moriya, & Raes, 2017). In this online version, participants provide written responses to cue words over a series of sessions. Feedback is given after they submit each response via a computerised algorithm that is trained using machine learning to distinguish between written specific and non-specific autobiographical memories (Takano et al., 2017, 2018). Two subsequent studies by Martens and colleagues in older adults (Martens et al., 2019) and in adults with a history of depression (Martens, Barry, Takano, Onghena, & Raes, 2019) also showed evidence that c-MeST can significantly improve memory specificity.

The next step is to test c-MeST in a sample of individuals with clinical depression to evaluate whether it can also reduce depressive symptoms. Given that participants will not be exposed to interactions with a trainer or other group members and will focus solely on improving their recall of specific memories, this may be a stronger test of targeting this cognitive process in depression. Indeed, isolating this mechanism will mitigate against the possible confounds of common factor or interpersonal factors that occur in MeST.

The aim of this study was to conduct the first randomized controlled trial of online, computerized MeST in a sample of individuals with a Major Depressive Episode (MDE). Given the experimental nature of online MeST for depression, a no-treatment comparator group was chosen against which to test for clinical treatment efficacy. It was hypothesized that those in the c-MeST group will report a lower incidence of MDE and significantly lower levels of depressive symptoms at post-intervention and follow-up time-points, relative to the control group. It was also hypothesized that changes in memory specificity between pre- and post-intervention would predict changes in depressive symptoms post-intervention. In addition to this, a number of other secondary outcomes were assessed due to their association with memory specificity: rumination, cognitive avoidance, verbal fluency, problem-solving, suicidal Ideation, anxiety symptoms, and future thinking specificity.

Methods

The study was approved by the Deakin University Human Research Ethics Committee (identifier 2017_168) and registered on 8/9/2017 with the Australian New Zealand Clinical Trials Registry (ACTRN12618000257268). The protocol has been published (see Hallford, Austin, Raes, & Takano, 2019). CONSORT guidelines were followed (Schulz, Altman, & Moher, 2010)

Study Design

A pre-registered online, randomized-controlled trial, using a two (condition: c-MeST vs. control group) x four (time-point: baseline, post-intervention, one- and three-months post-intervention) factorial-design. Participants were allocated using simple 1:1 randomization by computer.

c-MeST Program

The program comprised seven sessions based on content from validated methods of improving memory specificity in face-to-face (Raes et al., 2009) and online formats (Takano et al., 2017). Participants engaged in practice providing specific autobiographical memories to a series of cues words in each session and received feedback of whether these were specific or not via an algorithm developed to classify written autobiographical memories (Takano et al., 2018). Full details of the program are in the published open-access protocol (Hallford et al. 2019). Participants completed the modules at their convenience over a two-week period, but were advised not to do multiple sessions in one day. This two-week period was chosen as it was thought that participants might be motivated to complete the program if the availability was limited, and this two-week window had been sufficient in a previous study to improve memory specificity (Takano et al., 2017). The program was not optimized for mobile phone use, and it was recommended to participants that it was completed on laptop/personal computer.

Participants and recruitment

Recruitment occurred from August 2018 to August 2019, via advertisements in a range of online formats, such as depression-related internet forums, social media platforms, and advertising on Facebook.

The inclusion criteria, assessed through self-report, were: (i) ≥ 18 years of age, (ii) residing in Australia, (iii) English-speaking, (iv) current diagnosis of a Major Depressive Episode, (v) score of ≥ 10 on the Patient Health Questionnaire (PHQ; Spitzer et al., 1999) and (vi) internet access in the home. The exclusion criteria, also assessed through self-report, were: (i) currently receiving treatment for depression, with the exception of antidepressant medication stable in type and dosage for at least four weeks, and (ii) PHQ scores of ≥ 21 , indicative of highly severe depressive symptoms. Therefore, the sample included those with severe symptoms, but excluded highly severe. This imposed by the approving ethics board due to the lack of provision for assertive follow-up. Participants were asked at each time-point whether they had received any treatment for their

depression or another mental issue, with examples given, such as psychological therapy, medication, or support groups.

Primary outcomes

These were change in MDE diagnostic status and level of self-reported depressive symptoms at post-intervention, one, and three-month follow-up. MDE diagnostic status was assessed using the Electronic Psychological Assessment System (e-PASS; Nguyen et al., 2015). The e-PASS is an online, self-report clinical assessment system. The MDE module has 11 questions on the frequency of MDE symptoms over the last two weeks corresponding to the Diagnostic and Statistical Manual of Mental Health Disorders 5 (DSM-5; American Psychological Association, 2013). Items are answered using a scale from 0 (*not at all*) to 4 (*every day*), with one item for severity using a scale from 0 (*no interference/distress*) to 8 (*extremely significant interference/distress*). An algorithm is used to score the e-PASS, in concordance with DSM criteria, whereby if five symptoms occur either *more days than not* or *every day*, at least one of these is mood or anhedonia, and participants score $\geq$ three for interference/distress they are categorized as experiencing an MDE. An e-PASS diagnosis corresponds well with the Mini-International Neuropsychiatric Interview (Sheehan et al., 1998; Nguyen et al., 2015).

The PHQ (Spitzer et al., 1999) was used to assess depressive symptom severity. The PHQ has nine items corresponding to DSM-5 symptom criteria for an MDE. Rating scales from 0 (*not at all*) to 3 (*nearly every day*) indicate frequency of symptoms in the last two weeks and scores are summed to provide a total (range 0 – 27; average Cronbach's alpha across time-points = .76). The PHQ has excellent validity and reliability (Kroenke et al., 2010).

Secondary outcomes

Memory specificity was assessed using the Autobiographical Memory Test (Williams & Broadbent, 1986). Participants were asked to provide personal memories to 10 cue words, five positively and five negatively-valenced presented in alternating order. No time limit was given for

responses. Four sets of cue words were used, matched on their valence, arousal, and frequency of occurrence, using Bradley and Lang's (1999) affective norms for English words, and counterbalanced across time-points. A random sample of 200 responses were coded as specific or non-specific by the first author and another researcher blinded to condition and not otherwise associated with the study (Cohen's kappa for inter-rater reliability = .84), who then coded the remaining response. Scores were summed (range 0 -10; average Cronbach's alpha across time-points = .73).

Rumination was assessed using the Ruminative Responses Scale (Treynor, Gonzalez, & Nolen-Hoeksema, 2003). There were five items within each of the Brooding and Reflection subscales, which were summed with score range 5 – 20 (average Cronbach's alpha across time-points = .79 and .67, respectively). Cognitive avoidance was assessed with the White Bear Suppression Inventory (WBSI; Wegner & Zanakos, 1994), using 15 items which are averaged, with a score range of 1-5 (average Cronbach's alpha across time-points = .84). Verbal fluency was assessed using the Controlled Oral Word Association Test (COWAT; Ruff et al., 1995). Participants provide as many words as they can, within a one-minute time limit and excluding pronouns, starting with one chosen letter. A set of four letters (F, A, S, N.) were counterbalanced across time-points. The number of words were summed (intraclass correlation for inter-rater reliability in a subsample of 200 responses = .94). All participants were given an initial letter of E to respond to at baseline to help account for practice effects.

Problem-solving was assessed using the Means-End Problem Solving Procedure (MEPS; Platt, Spivak, & Bloom, 1971). Participants were presented with three common psychosocial problems and goals (e.g., having a bad diet and wanting to eat more healthily, having a rupture in a friendship and returning to a healthy relationship) and asked to provide in writing as many effective problem-solving steps as they could to reach the goal state. Nine problems were counterbalanced across the time-points. The responses were coded for total number of relevant problem-solving steps, as per standardized MEPS procedures (intraclass correlation for inter-rater reliability in a

subsample of 200 responses = .91). Scores were summed to represent number of relevant steps (average Cronbach's alpha across time-points = .75). The MEPS was not administered at the three-month follow-up due to lack of parallel versions.

Suicidal ideation was assessed by the Suicidal Ideation Attributes Scale (Spijker et al., 2014; five items summed, score range 0 – 50, average Cronbach's alpha across time-points = .87), and symptoms of clinical anxiety as assessed by the Generalized Anxiety Disorder Scale (GAD7; Spitzer et al., 2006; seven items summed, score range 0-21, average Cronbach's alpha across time-points = .87) given previous associations between anxiety and memory specificity (Hallford et al., 2019). Future thinking specificity was assessed at baseline and post-intervention using the Episodic Future Thinking Test (EFT-T; Hallford et al., 2019). The EFT-T uses methodology consistent with the AMT. For this study, five positive cue words were responded to and coded as specific or non-specific (Cohen's kappa for inter-rater reliability in subsample of 200 responses = .87) and summed (range 0 - 5; average Cronbach's alpha across time-points = .58). No time limit was given for responses. Although self-efficacy was planned to be assessed, an error in the online survey meant this data was not collected across time-points.

Evaluation Questions

Participants in the c-MeST group were asked five questions relating to their experience with the training program: "I found the memory training program easy to use", "I found the memory training program helpful", "I thought the memory training program was long enough", "I would recommend the training program to other people", "The feedback on whether my memories were specific was usually accurate". A five-point Likert scale was used (1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree*, 5 = *strongly agree*), and ratings of 1 or 2, and 3 and 5 were collapsed so responses were reported as percentages indicating Disagree, Neither Agree nor Disagree, or Agree.

Sample Size Calculation

The sample size was calculated under the following assumptions: (1) at least moderate group

difference (0.6 SMD) between the intervention and control groups for the primary outcomes, consistent with previous findings on between group differences in depressed samples with waitlist controls (Barry, Sze, & Raes, 2019); (2) power set at .80; (3) alpha set at .05 (two-tailed); and (4) expected attrition rate of 35% for the intervention group. Based on these parameters, G*Power version 3.1 (Faul et al., 2007) identified a required total sample of 105 participants across the two groups.

Data Analytic Plan

The main analyses were conducted by author M.F. who was blinded to condition. Consistent with our study protocol (Hallford et al., 2019), analyses followed the principles of intention-to-treat (ITT), with individuals retained in the group they were randomised to. Missing data were handled using full information maximum likelihood estimation for all analyses. Per protocol analyses were not conducted as there were too few cases that completed all measures at all time-points to make this viable (< 14 total). Pre-processing was conducted in IBM SPSS 26.0. Main analyses were conducted in Mplus Version 8.3. Post-intervention group differences in proportion of individuals with an MDE diagnosis were tested at each post-intervention timepoint using logistic regression. Baseline diagnosis was not controlled for as this was a condition of entry into the study. Post-intervention group differences for continuous variables were tested using linear mixed effects models, with main effects for time (dummy coded at each post-intervention timepoint relative to the baseline assessment) and group (intervention vs control), random effects for time dummy variables clustered within individuals, and time x group interactions to assess hypotheses about greater symptom improvement among the intervention group. An unstructured variance-covariance matrix was used for random effects, and no issues of non-convergence due to high correlation among the random effects were observed. Mediation analyses on change in scores was assessed with path analysis using group assignment at baseline as the IV, AMT scores at post-intervention controlling for scores at baseline as the mediator, and depressive symptoms at three-month follow-up controlling for scores at post-intervention as the DV. Mediation was calculated using bias-corrected

bootstrapping with 5000 samples.

Procedure

After providing informed consent, screening, and completion of the baseline survey, participants were randomized to groups. Participants in the c-MeST group were given two weeks access to the program, at which point their unique identifier code no longer allowed access. During the two weeks they received daily email prompts with links to the program to encourage them to access and complete it. Email reminders were sent to both groups at the follow-up points with links to the online surveys, which were completed using the Qualtrics survey platform. The experimenters were not blinded during this process. Participants in the control group were given access to the training program following the cessation of the study. Recruitment ceased when the estimated number of participants had completed three-month follow-ups.

Results

Participant flow and characteristics

In total, 2,813 individuals attempted screening for the study. Only 648 (23%) were screened as eligible, and 146 (22%) of these eligible individuals completed baseline measures, were randomized to a group and completed measures at a subsequent time-point (see Figure 1 for CONSORT flowchart). Table 1 shows the demographic characteristics. The sample was on average in their mid-40s and predominantly female. There were no significant differences on any demographic characteristics, including treatment for depression or other mental health issues. To assess factors that might have affected dropout, a series of *t*-tests and chi-square tests were conducted to assess for any differences at baseline between participants that completed the three-month follow-up versus participants that did not. Participants who did not complete the three-month measures were more likely to report receiving other treatment/support for mental health issues between baseline and one-month follow-up (52.8% vs. 29.3%, $\chi^2(1)=8.3$, $p=.004$). There was also a trend indicating that participants who did not complete the three-month follow-up had lower rates of casual employment (8.3% vs. 21.9%, $p=.070$). There were no other significant differences (all

$p's > .267$). Participants in the c-MeST group completed an average of 3.3 ($SD=2.6$) intervention modules, consistent with typically low adherence in unguided-internet intervention for depression (Webb, Rosso, & Rauch, 2017).

Primary outcomes group differences

There was no significant difference on rates of MDE diagnosis on the ePASS immediately post-intervention (45.8% c-MeST vs 57.6% control, Wald statistic=1.7, OR=0.62 95% CI [0.30, 1.26], $p=.188$; see Figure 2). A difference was found at one-month follow-up, with lower rates in the c-MeST group (35.7% c-MeST vs. 60.6% control, Wald statistic=4.4, OR=0.36 95% CI [0.14, 0.92], $p=.034$). However, there was no significant difference between the groups at three-month follow-up (26.5% c-MeST vs 34.2% control, Wald statistic=0.5, OR=0.69 95% CI [0.25, 1.91], $p=.478$).

As shown in Table 2, change in depressive symptoms on the PHQ did not differ between control and intervention group at post-intervention, but emerged as significant at the one-month follow-up, and also at the three-month follow-up with a moderate effect size (see Figure 3).

Autobiographical memory was the only variable to show significantly greater improvement in the intervention group by post-intervention, with these changes remaining significant and increasing in magnitude at follow-up points from moderate to large (see Figure 4).

Secondary outcomes group differences

The intervention group had significantly greater improvements in verbal fluency and the reflective rumination subscale relative to the control group by the one-month follow-up with moderate effects sizes, but this difference was not maintained at the three-month follow-up. Episodic future thinking, anxiety, problem solving, suicidal ideation, brooding rumination subscale, and cognitive avoidance did not significantly differ across groups at any of the timepoints, despite some small effect sizes that might be considered non-trivial (i.e., Cohen's $d > .2$).

Mediation effects

The proposed mediating effect of intervention on depressive symptoms via memory specificity was supported ($b=-0.55$, 95% CI [-1.56, -0.02]). Separately, the effect of group on

change in memory specificity was significant ($b=1.41$, 95% CI [0.38, 2.50]), though the subsequent effect of memory specificity on change in PHQ was non-significant ($b=-0.39$, 95% CI [-0.78, 0.06]). In the mediation model, the direct effect of group on PHQ was non-significant ($b=-2.03$, 95% CI [-3.87, 0.05]).

Program Evaluation

Half of the sample agreed the program was easy to use (Disagree=30%, Neither Agree nor Disagree=15%, Agree=55%). A third of the sample found it helpful, a third weren't sure and a third disagreed (Disagree=33%, Neither Agree nor Disagree=36.7%, Agree=30.3%). Half agreed it was long enough, and a third were undecided (Disagree=16.7%, Neither Agree nor Disagree=28.3%, Agree=55%). A third of the sample agreed they would recommend it to others, while a third weren't sure and a third disagreed (Disagree=33.3%, Neither Agree nor Disagree=33.4%, Agree=33.3%). Less than half agreed that feedback on responses in the program was usually accurate, and third disagreed (Disagree=36.7%, Neither Agree nor Disagree=21.7%, Agree=41.7%). No specific harms or unintended effects were identified.

Discussion

This study was the first to evaluate a computerized, automated version of Memory Specificity Training to improve specificity in autobiographical memory in clinical depression and alleviate depressive symptoms. Consistent with prior studies of c-MeST (Martens et al., 2019a, 2019b; Takano, Moriya, & Raes, 2017), improvements were found in the retrieval of specific, spatiotemporally-located personal memories in the c-MeST group, relative to control. This indicates that memory specificity can be improved in both depressed and non-depressed samples using online, automated methods.

MDE diagnostic status differed significantly between the groups at the one-month follow-up, but not at the three-month follow-up. For self-report symptom severity, an advantage for c-MeST emerged at one-month and was maintained at three-months. Together, these findings suggest that c-MeST could play a role in reducing depressive symptoms and speeding recovery. Few

previous studies comparing MeST to waitlist in clinical groups have included a follow-up, and findings have been mixed on depressive symptoms (Barry et al., 2019). Notably, one study that selected for participants with depression showed differences at follow-up (Neshat-Doost et al., 2013), whereas one that selected for posttraumatic stress disorder did not (Moradi et al., 2014). These current findings support the notion that when clinically depressed participants engage in MeST, effects on depression might be maintained beyond short-term follow-up.

Some differences were found for verbal fluency and rumination at one month follow-up, but not other time-points or on other secondary measures. These findings reflect the inconsistency with which these variables are found to be related to memory specificity. For example, rumination has been posited as associated with, and perhaps causal in, rAMS in depression (Williams et al., 2007). However, recent meta-analytic evidence contradicts this, showing rumination is not correlated with memory specificity, even in depressed samples (Chiu et al., 2018). Further, Barry et al.'s (2019) review indicates inconsistent findings for MeST's effects on verbal fluency and rumination, and no effects for problem-solving at follow-ups. We also assessed future thinking specificity at pre and post-training, with a non-significant, small-to-moderate between-group difference. This may be due to poor internal reliability in this study or low participant motivation, given it was at the end of the survey. This notwithstanding, if psychometric issues are addressed then future specificity may be of interest to assess in future studies, as it is closely related to memory specificity and may show change at subsequent follow-up.

Changes in memory specificity were found to mediate subsequent changes in depressive symptoms. Previous research on mediation effects have been mixed, with a small, early trial showing evidence for this change process (Neshat-Doost et al., 2013), but a more recent trial showing no mediation effect compared to an active control that was not targeting memory specificity (Werner-Siedler et al., 2018). This study provides further support for the mechanism of change in MeST, that increases in memory specificity drive subsequent effects on depressive symptoms. Nevertheless, this may not fully explain the effects of MeST on depressive symptoms.

Further exploration is needed to ascertain which other variables in MeST might act as mechanisms of change in reducing depressive symptoms. Given that participants are retrieving memories with a range of personal content this may facilitate reappraisal of beliefs about oneself or one's life. Therefore, candidate variables might include self-related variables such as self-construals/self-schema, meaning in life, or a more cohesive narrative identity (Hallford & Mellor, 2017). Another possibility is that MeST may promote experiential processing, that is, processing of past experiences in a direct and non-judgmental way. Experiential processing has been shown to increase positive emotional response during recall (Gadekis, Bos, Schweizer, Murphy, & Dunn, 2017), which may help address anhedonia in depression.

Limitations

In general, participant feedback on the c-MeST program was not particularly positive. c-MeST lacks the social, supportive environment and positive feedback and encouragement from other participants and facilitator that face-to-face, or off-line MeST offers. Responses on the evaluation questions strongly indicate that c-MeST requires modification to make the user experience more interesting and engaging. Overall, participants did not agree that the feedback on specificity in the program was accurate. This is interesting given that the algorithm has achieved a classification accuracy of over 80% (Takano et al., 2018). Further testing of this algorithm may be needed to understand whether this accuracy is compromised in individuals with depression. Alternatively, some participants may not be learning how to provide specific memories in the context of limited, dichotomous feedback (correct/incorrect). Perhaps relatedly, mean AMT scores were still low in the c-MeST group at the three-month follow-up. It is worth noting, however, that this mean score was not dissimilar to the average number of specific responses provided by community samples in paper and pencil formats of the AMT (Griffiths et al., 2009). This may also be an artefact of reduced participant motivation/effort in online delivery, in the absence of an experimenter. In this study we chose internet-administered AMT to reduce burden on participants and researchers, and increase accessibility. However, future research may opt for face-to-face administration, for example on

video conferencing, to better control for task adherence when assessing outcomes. Regardless, there is significant room for improvement in feedback in c-MeST to improve learning of how to retrieve specific memories and mastery of this task, and to improve user experience. The c-MeST application was not optimized for mobile phone use. Although participants were advised to use it on personal computer/laptop, some negative feedback regarding usability may relate to this. Future iterations of c-MeST could rectify this.

Future studies examining c-MeST might incorporate changes to the program and design as above, in order to more robustly test the effects of this online intervention. A longer-term follow-up would be informative, and provide scope to test mediation at different time lengths. C-MeST might be tested in other clinical groups that have shown response to MeST, such as posttraumatic stress disorder (Moradi et al., 2014). Future research might also incorporate c-MeST into other interventions. A study examining c-MeST as an adjunct to other treatments for depression is currently underway (Hallford et al., 2020). Integrating c-MeST into treatments that already target autobiographical memory, such as reminiscence therapies, might provide further enhancement of change processes (e.g., Kleijn et al., 2018; also see Piquart & Forstmeier, 2012).

In conclusion, the study provides evidence that c-MeST can improve memory specificity and depressive symptoms in those with a MDE, and may speed the rate of recovery. Future studies can examine further the mechanism/s through which this occurs.

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Competing interests statement.

FR is one of the developers of the original in-group face-to-face MeST and of the online, computerized MeST (c-MeST). FR additionally receives payments for training workshops and presentations related to MeST. There are no other competing interests to declare

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Figure 1. Participant Flowchart

Figure 2. *Outcomes for the ePASS*

Figure 3. Outcomes for Depressive Symptoms on the PHQ (with 95% CI of SD)

Figure 4. *Outcomes for Memory Specificity (with 95% CI of SD)*

Table 1.

Characteristics of Participants

Characteristic	Full Sample	Control	c-MeST	Statistics
Age	46.1 (<i>SD</i> = 13.3)	47.2 (<i>SD</i> = 11.8)	45.0 (<i>SD</i> = 14.6)	$t = 1.0, p = .312$
Number of Females	131 (89.7%)	66 (89.2%)	65 (91.5%)	$\chi^2 = 0.2, p = .631$
Level of Education				$\chi^2 = 4.6, p = .331$
Primary School	1 (0.7%)	0	1 (1.4%)	
High School	25 (17.1%)	9 (12.2%)	16 (22.2%)	
Diploma	54 (37%)	30 (40.5%)	24 (33.3%)	
Undergraduate	44 (30.1%)	25 (33.8%)	19 (26.4%)	
Degree				
Postgraduate	22 (15.1%)	10 (13.5%)	12 (16.7%)	
Degree				
Currently Studying	21 (14.6%)	8 (11.1%)	13 (18.1%)	$\chi^2 = 1.3, p = .238$
Employed	90 (61.2%)	47 (62.6%)	43 (59.7)	$\chi^2 = 5.0, p = .165$
Ethnicity				$\chi^2 = 4.2, p = .375$
Caucasian/White	136 (93.2%)	71 (95.9%)	65 (90.3%)	
European				
Asian	4 (2.7%)	2 (2.7%)	2 (2.8%)	
African	2 (1.4%)	1 (1.4%)	1 (1.4%)	
Arab/Middle	1 (0.7%)	0	1 (1.4%)	
Eastern				
Other	3 (2.1%)	0	3 (4.2%)	
Other	60 (40.8%)	30 (30.6%)	30 (29.4%)	$\chi^2 = 0.04, p = .837$
Treatment/Support for Mental Health During the Trial				

Table 2.

Comparison of Outcomes between Intervention and Control Groups across Time

Outcomes	Control Group		c-MeST Group		Adjusted difference (c-MeST - control)		
	<i>N</i>	Mean (<i>SD</i>)	<i>N</i>	Mean (<i>SD</i>)	Mean (95% CI)	Cohen's <i>d</i>	<i>p</i> - value
PHQ9							
Baseline	74	17.58 (3.02)	72	17.67 (3.36)			
Post-int	65	14.70 (5.01)	57	13.46 (6.06)	-0.71 (-2.55, 1.13)	0.14	.448
1-mpost	33	14.35 (4.47)	42	11.57 (4.65)	-2.56 (-4.64, -0.49)	0.57	.015
3-m post	36	13.53 (5.15)	32	10.47 (3.95)	-2.77 (-4.75, -0.79)	0.67	.006
AMT							
Baseline	72	3.40 (2.37)	70	3.40 (2.24)			
Post-int	51	3.12 (2.29)	40	4.63 (2.73)	1.40 (0.30, 2.51)	0.53	.013
1-mpost	29	2.90 (2.60)	32	4.41 (3.18)	1.64 (0.41, 2.86)	0.68	.009
3-m post	31	2.52 (2.11)	28	4.89 (2.54)	2.03 (0.90, 3.16)	0.94	<.001
COWAT							
Baseline	71	12.44 (3.87)	69	12.91 (4.31)			
Post-int	51	13.00 (4.76)	42	13.43 (4.53)	-0.30 (-2.02, 1.43)	0.07	.738
1-mpost	29	10.48 (3.49)	32	11.62 (3.25)	1.80 (0.03, 3.57)	0.52	.047
3-m post	31	14.35 (6.43)	27	12.85 (4.72)	-1.14 (-3.43, 1.15)	0.26	.218
EFT-T							
Baseline	68	1.79 (1.41)	68	1.69 (1.40)			
Post-int	44	1.02 (1.32)	38	1.33 (1.29)	0.44 (-0.20, 1.08)	0.30	.181
GAD7							
Baseline	70	13.40 (4.43)	68	13.18 (4.78)			
Post-int	46	12.41 (4.74)	36	10.61 (6.08)	-0.55 (-2.80, 1.70)	0.11	.634
1-mpost	20	10.60 (3.44)	28	9.07 (4.12)	-1.60 (-3.57, 0.37)	0.47	.111
3-m post	31	10.74 (5.23)	18	10.33 (5.06)	0.14 (-2.15, 2.42)	0.03	.908
MEPS							
Baseline	72	18.36 (6.98)	68	19.09 (8.96)			
Post-int	46	19.37 (8.23)	38	20.87 (9.40)	0.31 (-2.85, 3.48)	0.05	.846
1-mpost	25	21.08 (10.79)	31	23.58 (10.04)	0.66 (-4.12, 5.44)	0.07	.787
RRS-B							
Baseline	71	13.93 (3.08)	68	13.90 (3.34)			
Post-int	51	14.02 (3.55)	42	13.45 (3.51)	0.14 (-1.06, 1.33)	0.05	.821
1-mpost	29	13.79 (3.65)	32	13.44 (3.19)	-0.17 (-1.56, 1.22)	0.06	.810
3-m post	31	12.84 (4.04)	26	12.31 (3.73)	-0.15 (-1.86, 1.56)	0.05	.862

Note. The adjusted difference reflects the group x time interaction.

Table 2. continued...

Outcomes	Control Group		c-MeST Group		Adjusted difference (c-MeST - Control)		
	No.	Mean (SD)	No	Mean (SD)	Mean (95% CI)	Effect size	P value
RRS-R							
Baseline	72	12.72 (2.78)	69	13.07 (3.11)			
Post-int	52	13.33 (3.03)	42	12.50 (3.52)	-0.76 (-1.93, 0.42)	0.26	.208
1-mpost	29	14.10 (3.17)	32	12.22 (2.88)	-1.45 (-2.81, -0.08)	0.54	.038
3-m post	29	12.97 (3.03)	27	11.81 (2.73)	-0.86 (-2.25, 0.54)	0.33	.228
SIDAS							
Baseline	72	10.56 (9.98)	65	13.54 (11.37)			
Post-int	52	10.85 (9.57)	42	10.48 (12.20)	-1.88 (-5.19, 1.42)	0.23	.265
1-mpost	29	10.66 (10.15)	32	11.03 (12.57)	-2.92 (-6.71, 0.87)	0.39	.131
3-m post	31	7.68 (10.14)	27	9.74 (9.34)	-3.72 (-8.71, 1.27)	0.39	.144
WBSI							
Baseline	67	4.00 (0.40)	69	4.08 (0.58)			
Post-int	52	3.84 (0.43)	40	3.80 (0.65)	-0.12 (-0.33, 0.09)	0.24	.250
1-mpost	28	4.03 (0.41)	31	3.87 (0.59)	-0.18 (-0.40, 0.03)	0.44	.095
3-m post	28	3.55 (0.41)	27	3.58 (0.40)	-0.07 (-0.31, 0.17)	0.15	.573

Note: PHQ = Patient Health Questionnaire-9, AMT = Autobiographical Memory Test, COWAT = Controlled Oral Word Association Test, EFT-T = Episodic Future Thinking-Test, GAD = Generalized Anxiety Disorder Scale, MEPS = Means-End Problem Solving, RRS-B = Ruminative Response Scale – Brooding Subscale, RRS-R = Ruminative Response Scale – Reflective Subscale, SIDAS = Suicidal Attributes Scale, WBSI = White Bear Suppression Inventory. The adjusted difference reflects the group x time interaction.