**Supplementary Methods.**

**Inclusion and exclusion criteria**

Exclusion criteria for the randomizes controlled trial (RCT) included: a diagnosis of major depressive disorder (MDD) during the past year, a lifetime history of bipolar disorder, currently taking psychiatric medications or undergoing psychotherapy, possibility of acute suicide attempts, difficulty in understanding the purpose of the study, difficulty in completing the self-report scales due to a serious mental condition, or severe physical illness. An additional exclusion criterion for the magnetic resonance imaging (MRI) study was a contraindication for magnetic resonance. No participants smoked, or consumed alcohol or drugs (including cannabis use) during the study period. Clinical improvement was monitored by administering the BDI-ll and Environmental Reward Observation Scale (EROS). Each measure was carried out at baseline (Time 1) and after 5 weeks (Time 2) in both groups.

**Treatment**

This program focused on expanding positively reinforcing activities in order to increase the rate of response-contingent positive reinforcement, so that participants could experience a sense of self-control and motivation. The initial session of the program consisted of psycho-education about depression, in which participants learned to assess their long and short-term goals, and develop activity monitoring skills. Session 2 focused on constructing a behavioral hierarchy consisting of 10 tasks that gave participants a sense of reward. Sessions 2-4 focused on behavioral experiments and increasing scheduled activities. Session 5 consisted of reviewing behavioral activation (BA) and developing a personal plan for coping with future stressful situations. Every session, except for Session 5, included a homework assignment. Further information about this program is available in our previous report 1.

**MRI acquisition**

The functional (f)MRI procedure was performed using a Magnetom® Verio3T (Siemens, Munich, Germany). A time-course series of scans was acquired using T2\*-weighted, gradient echo, echo planar imaging (EPI) sequences. Each volume consisted of 40 slices, with a slice thickness of 3mm with no gap, and covered the entire cerebral and cerebellar cortices. The time interval between two successive acquisitions of the same image (TR) was 2,500 ms, the echo time (TE) was 25 ms, and the flip angle was 90°. The field of view (FOV) was 192 mm, and the matrix size was 64 × 64, resulting in voxel dimensions of 3 mm ×3mm × 3 mm. Scan acquisition was synchronized to the onset of each trial. After functional scanning, structural scans were acquired using a T1-weighted gradient echo pulse sequence (TR = 2300 ms; TE = 2.98 ms; flip angle = 9°; FOV = 256 mm; voxel dimensions of 1 mm × 1 mm × 1 mm) to facilitate localization.

**fMRI data preprocessing and statistical analysis**

The first three volumes of each fMRI run were discarded because the MRI signal was unsteady, and the remaining volumes were used for the statistical analysis. A slice-timing correction was applied to correct for differences in image acquisition between slices. Each set of functional volumes was realigned to the mean volume. Volumes were spatially normalized to a standard template based on the Montreal Neurological Institute (MNI) reference brain, and smoothed using a 6-mm full-width at half maximum Gaussian kernel. For the statistical analysis, t-contrast images of each subject were calculated using a general linear model that included four conditions; presentation of the stopwatch (SW) task cue and watchstop (WS) task cue, and success or failure feedback of the SW task. Six regressors describing residual motion were included as an additional regressors of no interest.

**1** Takagaki K, Okamoto Y, Jinnin R, Mori A, Nishiyama Y, Yamamura T, et al. Behavioral activation for late adolescents with subthreshold depression: a randomized controlled trial. *European child & adolescent psychiatry* 2016; **25**: 1171-82.

**Supplementary Table**

Supplementary Table1. Behavioral data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Intervention group | Non-intervention group | Statistical value | P value |
| Time 1 |  | Time 2 |  | Time 1 |  | Time 2 |  |  |  |
| Mean | SD | Mean | SD | Mean | SD | Mean | SD |  |  |
| Response time for SW (ms) | 4970 | 189.9 | 4991 | 199.8 | 4973 | 197.5 | 5023 | 32.2 | 0.57, F1-49 | 0.46 |
| Success rate of SW (%) | 55.1 | 15.5 | 50.4 | 15.9 | 55.0 | 12.9 | 56.5 | 14.3 | 1.75, F1-49 | 0.19 |
| IMI score | 6.3 | 2.5 | 5.7 | 2.9 | 5.8 | 2.7 | 5.4 | 3.1 | 0.04, F1-49 | 0.84 |

Supplementary Table2. Changes in brain activity between Time1 and Time2

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Region | BA | Side | Z | p | kE | x | y | z |
| Cue presentation phase |
| ***Intervention group> non-intervention group*** |
| Whole brain |
| Middle frontal gyrus  | 8 | R | 4.41 | 0.029 | 97 | 30 | 30 | 36 |
| Superior frontal gyrus  | 9 | R | 4.38 | 0.010 | 121 | 14 | 52 | 34 |
| Anterior cingulate gyrus | 32 | R | 4.10 | 0.044 | 88 | 6 | 32 | 24 |
| ROI analysis |
| Putamen |  | L | 4.02 | 0.018 | 39 | −20 | 14 | 4 |
| ***Intervention group< non-intervention group*** |
| No significant difference |

A significant group × time interaction was elicited by the task cue period in response to the stopwatch (SW) relative to the watchstop (WS) trials. The voxel-wise variation in the intervention group across time was greater than that of the non-intervention group (i.e., intervention > non-intervention). Activation is reported at p < 0.05 for multiple comparisons at the cluster level. BA. Brodman area; L, left; R, right; Z, Z value of the peak activation within the cluster; coordinates of the peak voxel are listed as Montreal Neurological Institute (MNI) coordinates; p, corrected p value at the voxel level.

Supplementary Table3. Changes in right middle frontal gyrus connectivity in during SW task cue presentation relative to WS task cue presentation between Time 1 and Time 2

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Region | BA | Side | Z | p | kE | x |  | y | z |
|  | SW task cue presentation relative to WS task cue presentation |
|  | ***Intervention group> non-intervention group*** |
|  | Whole brain |
| Posterior cingulate cortex | 31 | R | 4.50 | 0.005 | 131 | 6 |  | -40 | 50 |
|  | ***Intervention group< non-intervention group*** |
|  | No significant difference |

The results are reported at p < 0.05 for multiple comparisons at the cluster level. Psychophysiological interaction (PPI) analyses using the right middle frontal gyrus as a seed.