Retrieval Stopping Can Reduce Distress from Aversive Memories

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Abstract

Aversive memories have the potential to impair one's psychological well-being. It is desirable to reduce the anguish over such memories, as well as the chance that they will be retrieved. In two experiments, we investigated whether retrieval stopping reduces the distress elicited by negative memories retrieved from cues and how the effects of retrieval stopping are modulated by mental disorders, such as depression and anxiety. Participants engaged in retrieval stopping of aversive scene memories without any diversionary thoughts (direct suppression, Experiment 1) or with diversionary positive thoughts (thought substitution, Experiment 2). Direct suppression reduced arousal elicited by the retrieval of aversive memories, while thought substitution did not only reduce arousal but also increased positive valence. Self-reported anxious/depressive symptoms negatively modulated the effects of direct suppression. For no or mild anxious/depressed individuals, direct suppression alleviated negative valence and high arousal when retrieving aversive memories. The negative relationship was not observed between the severity of the symptoms and the effect of thought substitution. These findings suggest that both retrieval stopping strategies can reduce distress from aversive memories.

keywords: Retrieval stopping, Emotion regulation, Think/No-Think, Depression, Anxiety

Retrieval Stopping Reduces Distress from Aversive Memories

Memories evoke emotions. We feel happy when remembering joyful past events and motivated when thinking about future rewards. In contrast, we become upset when remembering stressful past events, and anxious or nervous when thinking about future failure. Such negative emotions have the potential to impair mental health, leading to mental disorders. Thus, the ability to control what we remember, especially to stop retrieving unwanted memories, plays an important role in maintaining our mental well-being. Previous studies have shown that we can stop retrieving (unwanted) memories, and this retrieval stopping leads to forgetting of memories (for a review, see Anderson & Huddleston, 2012). A growing body of evidence also suggests that retrieval stopping contributes to regulating negative emotions (Engen & Anderson, 2018). In the present study, we provide further evidence for the effect of retrieval stopping on emotion.

Retrieval stopping has been investigated using the Think/No-Think (TNT) paradigm (Anderson & Green, 2001). In this paradigm, participants first learn cue-target pairs. Then they perform the critical TNT task, in which they are given only the cues and instructed to retrieve (Think) or to stop retrieving (No-Think) the corresponding targets. After performing Think or No-Think attempts repeatedly (typically over 10 times) in the TNT task, a cued recall test is administered in which participants are asked to remember all the cued targets regardless of the instructions in the TNT task. In the test, participants recall fewer No-Think targets than Think targets as well as Baseline targets that are learnt in the initial study phase but not manipulated during the TNT task (below-baseline forgetting; for a review, Anderson & Huddleston, 2012). That is, retrieval stopping can cause forgetting of unwanted memories. Forgetting by means of retrieval stopping has been observed with a variety of stimuli, such as words (Anderson et al., 2004), scenes (Küpper et al., 2014), and autobiographical memories (Noreen & MacLeod, 2013), even when these stimuli were negatively valenced (e.g., Hertel & McDaniel, 2010; van Schie et al., 2013). Several studies have reported that participants experience fewer intrusions of targets as they repeat No-Think attempts during the TNT task (e.g., Levy & Anderson, 2012).

Recent TNT studies have demonstrated that retrieval stopping influences not only later recall but also later self-reported and physiological emotional reactions (Gagnepain et al., 2017; Harrington et al., 2020; Legrand et al., 2020). For example, Gagnepain et al. (2017) conducted a TNT experiment in which highly aversive images were used as targets. After the TNT task, participants rated the valence of the images presented on the display. Individuals with higher memory control ability (defined as fewer intrusions during the TNT task) rated No-Think images less aversive than Baseline images, whereas individuals with lower memory control ability rated No-Think images more aversive than Baseline images. Moreover, Harrington et al. (2020) showed that retrieval stopping reduced skin-conductance response, which is a physiological measure of emotional arousal, toward negative scene images. These findings suggest that retrieval stopping can attenuate subjective and physiological emotional responses induced by aversive images.

Although these studies collected affective ratings of, or physiological responses to, aversive images presented on a display (referred to as exogenously elicited emotions by Engen and Anderson, 2018), emotions are also elicited by the retrieval of memories (endogenously elicited emotions; Engen & Anderson, 2018). Remembering negative memories induces negative emotions and possibly impairs psychological health. Thus, it is important to examine whether retrieval stopping can also reduce the distress elicited by retrieving aversive memories.

To examine the emotion regulation effect of retrieval stopping, it is important to recognize that there are two distinct strategies of retrieval stopping: direct suppression (e.g., Bergström et al., 2009) and thought substitution (e.g., Hertel & Calcaterra, 2005)[1]. Direct suppression is a strategy of suppressing memories by focusing only on cues and pushing away other thoughts, including unwanted memories, from awareness. Thought substitution is a way to avoid thinking of unwanted memories by employing diversionary thoughts (substitutes). Although both strategies cause similar amounts of forgetting (Stramaccia et al., 2020), different mechanisms are involved (Benoit & Anderson, 2012). Specifically, direct suppression involves inhibitory control, resulting in memories less likely remembered (Anderson & Green, 2001; Anderson & Hulbert, 2021; Taubenfeld et al., 2019; Wang et al., 2019). On the other hand, thought substitution involves selective retrieval of substitutes, which interfere with target retrieval (Wang et al., 2015); however, some studies have reported that inhibitory control also underlies thought substitution (Benoit & Anderson, 2012; del Prete et al., 2015). Because of these differences, the two strategies should influence endogenously elicited emotion in different ways. Direct suppression should alleviate distress by impairing the retrieval of memory traces, and memories with less detail should induce less distress. Furthermore, because memory and emotion processes are regulated in parallel (Gagnepain et al., 2017), engaging in direct suppression should devalue aversive memories independently of impairment of memory representations. In contrast, thought substitution should alleviate distress by interference of substitutes with the

[1] It should be noted that "retrieval stopping" is not always used as an umbrella term for direct suppression and thought substitution. Some recent studies seem to refer to retrieval stopping and direct suppression as equivalent (e.g., Anderson & Hulbert, 2021). Furthermore, there is no term covering the two strategies that TNT researchers have agreed upon. Nevertheless, we use "retrieval stopping" here as an umbrella term, following Bergström et al. (2009), who were the first to compare the two strategies and referred to them as "strategies for retrieval stopping" (p. 728).

evaluation of distress from target aversive memories, as well as by memory inhibition. Because substitutes are associated with cues through thought substitution, substitutes would be retrieved when participants retrieve targets from cues. The retrieval of substitutes would distract participants from evaluating the distress from the target retrieval. In addition, emotion elicited by substitute retrieval would bias the evaluation of emotion elicited. If this is the case, thought substitution alleviates distress from aversive memories when the substitute memories are comfortable (more positive and less arousal).

Mental health should also be considered as a factor that modulates the effect of retrieval stopping. Previous TNT studies have shown that the efficiency of retrieval stopping is negatively associated with a variety of mental disorders or symptoms related to them, such as anxiety (Marzi et al., 2014; Waldhauser et al., 2011), depression/dysphoria (e.g., Zhang et al., 2016) and rumination (Dieler et al., 2014; Fawcett et al., 2015). Although there are only a few studies that gave participants direct suppression instructions for the No-Think strategy (see Stramaccia et al., 2020), the studies demonstrated that (sub-)clinical sample showed less forgetting of negative memories by direct suppression supposedly due to inhibitory dysfunction (Fawcett et al., 2015; Marzi et al., ,2014; Zhang et al., 2016). In addition, the literature on emotion regulation shows that anxious/depressive symptoms are linked to emotion dysregulation (e.g., Everaert & Joormann, 2019). According to these findings, it was expected that anxious/depressed individuals would fail to attenuate distress from retrieved aversive memories through direct suppression. Indeed, Benoit et al. (2016) found that trait anxiety was negatively associated with the effects of direct suppression on apprehensiveness toward future events. On the other hand, it is unclear whether anxious/depressive symptoms modulate the effect of thought substitution. Although a few studies have examined the relationship between forgetting by thought substitution and anxious/depressive symptoms, the results are not consistent: Joormann et al. (2009) observed forgetting by thought substitution among participants who suffered from major depressive disorder (see also Hertel & McDaniel, 2010), but Noreen and Ridout (2016a, 2016b) did not find such effects among dysphoric participants and others in whom dysphoric mood was induced. Despite the inconsistency on the relationship between forgetting by thought substitution and depression, it was expected that thought substitution with comfortable memories led to the hypothetical interference effect of thought substitution described above regardless of anxious/depressive symptoms, which would alleviate distress toward negative memories. Through repeated thought substitution during the TNT task, even anxious/depressive individuals might be able to create associations between cues and substitutes and learn to retrieve substitutes from cues. As shown by Noreen and Ridout (2016a, 2016b), it was likely that they still remembered negative memories even after they performed thought substitution because anxious/depressive individuals have biased attention towards negative information and tend to retrieve mood congruent memory (e.g., Joormann, 2010; Moran, 2016; Norris et al., 2019). However, if the cue-substitute association was learnt adequately, they would retrieve the substitutes together when they retrieve targets from the cues, which would distract and bias the affective evaluation of the targets. Therefore, contrary to possible negative relationships between anxious/depressive symptoms and forgetting by thought substitution, those symptoms would not be associated (if any weakly) with the interference effect of thought substitution.

We conducted two TNT experiments to examine whether each of the two retrieval stopping strategies alleviates distress elicited by retrieving aversive memories. We also investigated how anxious/depressive symptoms modulate the effects of retrieval stopping on emotion. In both experiments, participants learned pairs of neutral objects and negative scenes and then performed a TNT task in which they engaged in retrieval stopping. Participants received instructions for direct suppression and thought substitution in Experiments 1 and 2, respectively. We collected valence and arousal ratings on scene memories retrieved from the presented object cues before and after the TNT task. By observing the difference in affective ratings between pre- and post-TNT tasks, we assessed whether retrieval stopping could alleviate distress from memories. Here, higher valence and lower arousal are considered as alleviation of distress, on the assumption that aversive scenes induce lower valence and higher arousal. We also calculated correlations between the alleviation effect and anxious/depressive symptoms. We predicted that both strategies would alleviate affective ratings of negative memories (i.e., higher valence and less arousal) through memory inhibition (direct suppression) and interference (thought substitution). However, we expected different relationships of alleviation effects and anxious/depressive symptoms between the two strategies. On the one hand, more severe anxious/depressive symptoms, which are related to poorer capability for direct suppression (Stramaccia et al., 2020), would be expected to reduce alleviation effects in the direct suppression group (Experiment 1). On the other hand, such negative correlations would not be observed in the thought substitution group (Experiment 2), because participants would retrieve not only targets but also substitutes from cues regardless of their symptoms, thus distracting and biasing the emotion evaluation of targets. The experiments were approved by the institutional ethics committee for experimental psychology research of the Graduate School of Education, Kyoto University (approval number CPE-256).

Experiment 1

Method

Participants

Thirty-six Japanese university students participated in Experiment 1. The data from six participants were excluded from the analyses for the following reasons. First, three participants skipped more than half of the valence/arousal ratings (> 29 of 60 items). We considered these numbers of missing values too large for reliable measures of the affective ratings, and the number of skipped ratings was much lower in the analyzed sample (M = 3.2, SD = 4.1). Second, two participants did not complete the experiment. Third, one participant did not follow the instructions. Data from 30 participants (17 males, mean age = 21.77, SD = 1.85) were analyzed. This sample size was determined based on a pre-experimental power analysis with the pwr package (1.2-2, Champely, 2018) of R 3.6.1 (R Core Team, 2020). The power analysis ensured that statistical power was higher than 80% when effect sizes of the difference between No-Think and Baseline were medium ($dz = 0.5$)[2] and sample size was greater than 26. For the power analysis and data analyses, we performed one-sided *t* tests because there were clear predictions for the directions of the differences in variables between the two conditions of interest (see the “Data Analysis” section for details)[3].

Materials

[2] The magnitude of effect sizes that would likely be obtained for the retrieval stopping effect on changes in affective ratings was unclear because few previous TNT studies have examined this effect. However, we expected a conventional medium effect size, based on the assumption that retrieval stopping would produce an effect size on changes in affective ratings similar to the size of forgetting in the TNT paradigm ($dz > 0.7$, in our previous studies; Nishiyama & Saito, 2021). *dz* represents the standardized mean difference effect size for within-subjects designs (Lakens, 2013).

[3] Some readers might be conservative in using one-sided *t* tests. The reason why we employed one-sided *t* tests was that we had clear predictions for the directions of the effect of retrieval stopping as in the main text, and that one-sided *t* tests can reflect more clearly the prediction as “the mean difference is greater/less than zero” compared to two-sided *t* tests in which the alternative hypothesis is that “the difference is not zero”. According to the decision, the power analysis for the sample size calculation was also performed assuming a one-sided *t* test. To keep consistency between the power analysis and actual hypothesis testing, the analysis should be one-sided *t* test in the current study.

The stimuli consisted of 60 object-scene image pairs. Object images were selected from the https://bradylab.ucsd.edu/stimuli.html database (Konkle et al., 2010). Scene images were selected from the International Affective Picture System (IAPS) database (Lang et al., 2008). Of the scenes, 30 were normed as negative (valence: M = 2.48, SD = 0.45; arousal: M = 5.63, SD = 0.87), 15 were neutral (valence: M = 5.14, SD = 0.34; arousal: M = 3.70, SD = 0.67), and 15 were positive (valence: M = 7.46, SD = 0.51; arousal: M = 4.67, SD = 0.61). The identifier numbers of the IAPS images were shown in Table S1. The scenes were randomly paired with object images. Two lists of 15 object-negative scene pairs were created, and each list was assigned to either the No-Think or the Baseline condition. Negative scenes in the two lists were matched for normed valence and arousal (mean valence difference = 0.02, mean arousal difference = 0.03). Assignment to condition was counterbalanced between participants. The 30 pairs of objects and positive/neutral scenes were randomly split into two lists, one containing 20 pairs, which were assigned to the Think condition, and the other list containing the remaining 10 pairs, which were used as fillers. An additional 120 IAPS scenes were used as new items in the recognition tests.

To measure anxious/depressive symptoms, we used the Japanese versions of the Beck Depression Inventory Second Edition (BDI-II; Kojima et al., 2002), State-Trait Anxiety Inventory (STAI; Hidano et al., 2000), and Ruminative Response Scale (RRS; Hasegawa, 2013). The BDI-II is a widely used questionnaire for assessing the presence and severity of depression that consists of 21 items rated on a 4-point scale. We did not include one item on suicidal ideation (item 9) because we were not able to provide treatment for those who gave this item a high score. We used the sum of the scores of the remaining 20 items as a depression score.

The STAI is a widely used questionnaire for assessing state and trait anxiety. Each section of the STAI consists of 20 items rated on a 4-point scale. We used the sum of the scores of all items in the state and trait sections as state and trait anxiety scores, respectively.

The RRS is a self-report measure of rumination. It consists of 22 items, each rated on a 4-point scale from 1 (*almost never*) to 4 (*almost always*). Twelve items of the RRS are confounded with depressive symptoms (Treynor et al., 2003); thus, we used the sum of the scores of the remaining 10 items as a rumination score.

Procedure

Experiment 1 consisted of eight phases (Figure 1A): encoding, drop-off/feedback cycles, recognition (time 1), affective rating (time 1), Think/No-Think (TNT) task, recognition (time 2), affective rating (time 2), and questionnaires. All phases were implemented using PsychoPy (1.90.1; Peirce, 2009) on a Mac Pro (macOS 10.13.6).

During the initial encoding phase, participants were presented with 60 object-scene pairs for 5 s each. After encoding, pair associations were strengthened through drop-off/feedback cycles (Figure 1B; Gagnepain et al., 2017). At the beginning of each trial, the participants were presented with cue objects. Then they pressed keys to indicate whether they were able to remember the corresponding targets. If participants pressed the right arrow key (indicating “yes”), three scene images appeared (a correct target and two targets associated with other cues), and participants were required to select the correct image by clicking it. After the selection, the correct target was presented as a feedback item for 3 s, regardless of whether or not participants had selected the correct image. If participants pressed the left arrow key to indicate that they could not remember the corresponding targets (“no”) at the initial stage of a trial, the correct target was presented without the image selection step. If participants could not identify the correct targets for any cues, they entered another drop-off/feedback cycle in which cues for targets that participants could not identify were presented. This cycle was repeated until all targets were correctly identified by participants.

After the drop-off/feedback cycles were completed, participants' memories were tested using an old/new recognition test (Figure 1D). During this phase, participants identified whether they had seen each scene on the screen before. They were given 120 scenes in total, comprising all 60 target scenes and 60 new scenes.

Subsequently, the participants performed an affective rating task. Each trial started with a cue object. During the 5 s presentation of the cue, participants were required to remember the corresponding target in as much detail as possible. Participants then rated the valence and arousal that they felt in remembering the scene on 9-point scales positioned below the cue. Each scale was accompanied by five manikins that expressed valence and arousal, respectively (Self-Assessment Manikins; Lang et al., 2008; Figure 1E). For valence ratings, five manikins with different facial expressions were aligned below the scale so that the manikins exhibited more pleasantness from left to right (leftmost: very unpleasant, rightmost: very pleasant). For arousal ratings, five manikins exhibiting different physiological conditions were aligned below the scale so that the manikins exhibited more excitement from left to right (leftmost: calm, rightmost: very excited). Participants were instructed to select by mouse click one of nine points, which included five points corresponding to the positions of the manikins and four points between two adjacent manikins. We converted their responses into numbers from 1 (the leftmost point) to 9 (the rightmost point). If participants could not remember the associated target, they skipped the rating task by pressing the right arrow key.

Following the first affective rating, participants performed the TNT task. They were instructed to retrieve (Think) or avoid retrieving (No-Think) the targets, while cues enclosed by a green or red frame were presented for 3 s, respectively. In particular, participants were given a direct suppression instruction for No-Think (e.g., Bergström et al., 2009), whereby they were to avoid thinking about targets by focusing on cues and pushing away the corresponding target, as well as any other diversionary thoughts, from their minds. After cue offset, a 3-point scale (*never*, *briefly*, and *often*) was presented on the screen for 1.5 s, and participants reported how often the associated scene had entered awareness by pressing one of the three buttons corresponding to the options (left, down, and right arrow keys, respectively; e.g., Levy & Anderson, 2012). If the rating time expired, a buzzer was presented for 1 s with the instruction “please rate” on the screen. After instruction and practice with filler pairs, 10 blocks of the main TNT task were conducted. In each block, all the Think and No-Think cues were presented once in a conditional random order in which more than two cues in the No-Think condition were not presented successively. The participants were given a 30 s break every two blocks. Throughout the TNT task, cues assigned to the Baseline condition were not presented.

After the TNT task, participants performed the recognition and rating tasks again in the same way as the first time.

Finally, participants completed all questionnaires in a fixed order (BDI, RRS, STAI-S, and STAI-T).

The inter-trial interval (ITI) was 500 ms for all phases, except for the questionnaires. Electrodermal activity was recorded throughout the experiment using a Biopac MP 150 System (Biopac, Inc., Goleta, CA, USA) and AcqKnowledge software (Biopac, Inc.). However, due to technical errors, the system missed recording signals that otherwise could have identified stimulus onsets in several trials for every participant. Thus, we did not conduct any analyses of these data.

Data Analysis

Through the procedure above, we obtained four behavioral measures. The first was the intrusion proportion for the No-Think attempts (or proportion of successful retrievals during the Think attempts) in the TNT task. The No-Think (or Think) trials where participants reported one (briefly) or two (often) for the intrusion ratings were counted as a trial with intrusion (e.g., Levy & Anderson, 2012). The intrusion proportion was the proportion of the intrusion trials to all trials. It was obtained for each block. Any trials without ratings were excluded from the computation of the intrusion proportion for each TNT block. The non-recognized items in the pre-TNT recognition test were also excluded, for reasons explained below. We contrasted intrusion proportions for the first and last TNT blocks to examine whether repeated attempts to suppress unwanted memories reduced their counter-intentional intrusion (Levy & Anderson, 2012). Specifically, we conducted a one-sided paired *t* test to determine whether the proportion of intrusions was smaller in the last block than in the first block.

The second behavioral measure was recognition performance, specifically the hit rate for the studied scenes. To examine forgetting by direct suppression, we contrasted the hit rates on the post-TNT recognition tests between the No-Think and Baseline scenes. The hit rate was a conditional probability calculated as the proportion of post-TNT recognition hits among the items that were correctly recognized in the pre-TNT recognition test (e.g., Anderson et al., 2004). We assumed that this conditionalized hit rate reflects the effect of inhibitory control more clearly than the standard hit rate that includes all test items in the post-TNT recognition test. Non-recognized items in the pre-TNT test were unlikely or less likely to intrude in response to the cue presentation during No-Think attempts[4] because those items were not properly associated with cues. Given that intrusions promote inhibitory control over unwanted memories (e.g., Levy and Anderson 2012), non-recognized items were less often subject to inhibitory control during the TNT task than recognized items. Therefore, post-TNT performance for the non-recognized items was less likely to be affected by inhibitory control. For this reason, we excluded non-recognized items on the pre-TNT recognition test from the analysis. We conducted a one-sided paired *t* test to confirm whether the mean hit rate of the No-Think scenes was lower than that of the Baseline scenes.

The third and fourth behavioral measures were valence and arousal ratings for each retrieved scene. To examine whether direct suppression reduced distress from the retrieved scenes, we calculated the difference in ratings for each scene between time 1 and time 2 (time 2 minus time 1; see Table S2 for the means and SDs of affective ratings at each time point). In the calculation, we excluded non-recognized items on the pre-TNT recognition test (for the reason explained above), as well as items whose ratings were skipped at either time point (Table S3). Then the obtained pre-post differences in valence and arousal (*Δ*valence and *Δ*arousal) were contrasted between No-Think and Baseline scenes, respectively. Specifically, we conducted one-sided paired *t* tests to examine whether *Δ*valence was larger for No-Think scenes than for Baseline scenes, and whether *Δ*arousal was smaller for No-Think scenes than for Baseline scenes. Here, one-sided *t* tests were applied, as we predicted the directions of the effects in advance.

[4] This trend was numerically observed in Experiment 1, but not in Experiment 2. As the number of non-recognized items was small, we did not conduct statistical tests.

To investigate how anxious/depressive symptoms modulate the effect of direct suppression on emotion, we calculated correlations between the direct suppression effect on affective ratings and scores on the four questionnaires[5]. To this end, we obtained alleviation scores of valence and arousal by calculating the differences between No-Think and Baseline conditions in pre-post differences (No-Think minus Baseline for *Δ*valence; and Baseline minus No-Think for *Δ*arousal). Positive values represent greater effects of direct suppression on valence/arousal.

Finally, we conducted exploratory regression analyses to examine how anxious/depressive symptoms predicted the effects of direct suppression on valence/arousal. Before the regression analyses, we conducted a principal component analysis (PCA) and summarized the four questionnaire scores, which could be independent variables, into two components. This enabled regression analyses without multicollinearity among the independent variables, which were expected to be highly correlated with each other. We then conducted multiple regression analyses for the alleviation scores of valence and arousal in which the principal components were independent variables. We did not include the interaction between the two PCs because there is no clear theoretical motivation on the interaction. To deal with potential inflation of false positive rate in exploratory multiple testing, p-values for the coefficients in a regression model were corrected by Holm's method. The corrected p values are referred to as p_{Holm} in the text.

[5] According to a reviewer's suggestion, we conducted repeated measures ANCOVAs on *Δ*valence and *Δ*arousal with each questionnaire score as a covariate, using JASP (JASP team, 2021). However, most of the results of the ANCOVAs for the data of Experiment 1 showed interactions between the main independent variable (No-Think vs. Baseline) and a covariate, indicating that homogeneity of regression slopes, an assumption of ANCOVA, was violated. Therefore, although such violations were not found in ANCOVAs on the data of Experiment 2, we decided to report correlation and regression analyses in the two experiments to maintain consistency of analytic approaches. The ANCOVA results may be found in JASP files (ancova_e1.jasp and ancova_e2.jasp) on the OSF repository.

All statistical analyses, except the ANCOVAs mentioned in footnote 4, were implemented in R 3.6.3 (R Core Team, 2020). All data and R scripts are available at Open Science Framework (https://osf.io/nep93/).

Results

Intrusion proportions for No-Think attempts

Figure 2A shows mean intrusion proportions for No-think targets (or successful retrieval proportions of Think targets) as a function of TNT block. A one-sided paired *t* test revealed that intrusion proportions decreased significantly from the first to the last block, $t(29) = 6.89$, $p < .001$, $dz = 1.26$, 95% CI [0.77, 1.73]. Consistent with previous studies (e.g., Levy & Anderson, 2012), repeated attempts to suppress memories reduced the counter-intentional retrieval of memories.

Recognition performance

Table S4 displays the mean hit rates for the studied scenes and the correct rejection rates for unstudied scenes. Figure 2B shows the conditionalized hit rates for No-Think and Baseline scenes in the post-TNT recognition test. A one-sided paired *t* test revealed a significantly lower mean hit rate for No-Think targets than for Baseline targets, $t(29) = -2.16$, $p = .019$, $dz = -0.39$, 95% CI [-0.76, -0.02]. The results indicate that scene memory inhibition occurred in the old/new recognition test.

Changes in affective ratings through direct suppression

Figures 2C and 2D show the pre-post differences (post minus pre) in valence and arousal (Δvalence and Δarousal). One-sided paired *t* tests revealed that Δvalence was not larger for No-Think scenes than for Baseline scenes, $t(29) = -0.67$, $p = .745$, $dz = -0.12$, 95% CI [-0.48, 0.24], while Δarousal was significantly smaller (i.e., decreased from pre- to post-rating to a greater extent) for No-Think scenes than for Baseline scenes, $t(29) = -2.07$, *p*

= .024, dz = -0.38, 95% CI [-0.75, 0.00]. The results suggest that across participants, direct suppression reduced arousal elicited by retrieved aversive scenes, but it did not alleviate valence.

Correlations with questionnaire scores

Figure 2E provides scatterplots and the corresponding correlations between each pair of the six scores (alleviation scores of valence/arousal and four questionnaire scores). The questionnaire scores were positively and strongly correlated with each other. The alleviation scores of valence and arousal were negatively correlated with each questionnaire score at a medium level (*r*s were around .4), indicating that participants who reported more severe anxious/depressive symptoms exhibited a smaller effect of direct suppression on valence/arousal.

Principal component analysis and regression analyses

The PCA revealed that two principal components (PCs) explained over 90% of the variance. According to the biplot shown in Figure S1, all four questionnaire scores contributed to the first PC (PC 1), suggesting that PC 1 represents the severity of symptoms without distinguishing between anxiety and depression. We therefore called PC 1 anxious/depressive symptoms. RRS and trait anxiety contributed positively to PC 2, while state anxiety and depression contributed negatively. Groups of scores were not formed based on the types of symptoms (i.e., anxiety or depression), but rather on the state-trait property of the scores. The RRS and STAI-T measure usual behavior or feeling, whereas the BDI and STAI-S measure recent behavior or feeling in the last two weeks (BDI) or at the present moment (STAI-S). In other words, PC 2 indicates which state or trait symptoms of anxiety and depression are reported with higher scores. This grouping may not be directly predictable from a theoretical perspective, but there is no theoretical conflict, because we assume that PC 2 does not reflect the characteristics of anxious/depressive symptoms. Thus, we defined PC 2 as the state-trait dominance of the symptoms, with a positive PC 2 score representing a higher trait score.

Subsequent regression analyses revealed that, the independent variables (i.e., two PCs) explained a significant proportion of variance in the alleviation scores (alleviation score of valence, R^2_{adj} = 0.20, $F(2, 27) = 4.70$, $p = .018$; alleviation score of arousal, R^2_{adj} = 0.15, $F(2, 27) = 3.53$, $p = .043$). The coefficients of anxious/depressive symptoms were significantly negative for both alleviation scores of valence and arousal (valence, $B = -0.09$, 95% CI [-0.15, -0.03], $\beta = -0.50$, $p = .006$, $p_{Holm} = .017$; arousal, $B = -0.13$, 95% CI [-0.22, -0.03], $\beta = -0.44$, $p = .016$, $p_{Holm} = .048$). These results indicate that individuals who reported more severe anxious/depressive symptoms alleviated negative valence and high arousal to a smaller extent than did individuals with no or mild symptoms. All results of the regression analyses are described in Table S5.

Discussion

The aim of Experiment 1 was to examine whether direct suppression alleviates distress from aversive memories and to identify the extent to which anxious/depressive symptoms modulate its effect. In the experiment, participants learned object-scene pairs, and then performed a TNT task in which they engaged in direct suppression to stop retrieval of a subset of aversive scenes. Consistent with previous studies, during the TNT task, participants reported less intrusion of No-Think targets across repeated No-Think attempts. In the old/new recognition test that followed the TNT task, participants recognized No-Think targets less accurately than Baseline targets (i.e., below-baseline forgetting). These results confirm that the participants successfully controlled their memories.

The results for affective ratings demonstrated that direct suppression attenuated arousal when aversive scene memories were retrieved later. Participants reported lower arousal elicited by No-Think target retrieval after the TNT task than before the TNT task, and the reduction in arousal rating was larger for No-Think targets than for Baseline targets. In contrast, valence ratings did not increase reliably through direct suppression. Importantly, the effects of direct suppression on valence/arousal were moderately correlated with questionnaire scores for anxious/depressive symptoms, as predicted. Individuals who reported no or mild symptoms exhibited greater effects on valence and arousal, while individuals who reported more severe symptoms showed the opposite effects (i.e., direct suppression increased their distress). These correlation results were confirmed by principal component regression analyses. Anxious/depressive symptoms, which was the first principal component of the questionnaire scores collected here, negatively predicted the effects on valence/arousal. That is, direct suppression reduced the distress of recalling aversive memories for individuals with no or mild anxiety or depression, but it produced the reverse effect, rather than a null effect, for individuals with more severe anxiety or depression.

The observed relationship between anxious/depressive symptoms and the effects of direct suppression on valence and arousal may have been mediated by memory inhibition ability. Previous studies have shown that individuals with (or at risk for) affective disorders exhibit less memory inhibition than healthy controls (e.g., Fawcett et al., 2015; Marzi et al., 2014). This difference may derive from attention/memory control deficits in anxiety and depression (Joormann, 2010; Moran, 2016). Because of poor memory inhibition ability, individuals with severe anxious/depressive symptoms may have experienced more intrusions of negative memories,[6] and/or failed to disengage from those memories, despite direct suppression attempts during the TNT task. Thus, aversive memories may have been remembered in as much detail during the affective ratings after the TNT task as during the ratings before the TNT task. In addition to deficits in memory inhibition, emotion regulation deficits in anxious/depressed individuals are well known (Sheppes et al., 2015). According to the parallel regulation hypothesis of memory and emotion via direct suppression (Gagnepain et al., 2017), people can regulate their emotion during repeated direct suppression attempts even if they fail to control the retrieval of aversive memories. However, anxious/depressed individuals cannot benefit from the emotion regulation aspect of direct suppression. For these reasons, individuals with stronger anxious/depressive symptoms exhibit smaller effects of direct suppression on affective ratings.

In this experiment, no task was administered to ensure that the participants recalled the corresponding targets during the affective rating tasks. Thus, it is possible the present results arose from participants' recall of non-target scenes during affective rating. Although this possibility cannot be completely excluded, few trials in which the wrong scenes were recalled contaminated the data, for the following reasons. First, participants were allowed to skip the rating task if they could not remember the corresponding targets, and those trials were excluded from the analyses. Second, in Experiment 2, participants still showed good performance on No-Think targets in the cued-recognition test after the TNT task. Thus, the number of contaminated trials was likely not large enough to change the present results.

Experiment 2

[6] It should be noted that this speculation about more intrusions in anxious/depressed individuals was not supported by an additional correlation analysis between intrusion proportion and questionnaire scores, in which weak correlations were found (*r*s around -0.1 to 0.1, see Figure S4).

Method

Participants

Forty-five Japanese university students participated in Experiment 2. The data from 15 participants were excluded for the following reasons. First, six participants failed to follow the TNT instructions at the end of the experiment, thus raising doubt about their compliance with the instructions during the TNT task. Second, three participants correctly recognized less than 30% of the target images in the post-TNT affective rating task. Those hit rates were regarded as outliers, given that the mean hit rate of the analyzed sample was almost 90%. Third, two participants skipped too many (i.e., more than 10) intrusion ratings during the TNT task. Many skipped ratings presumably reflect inattention to the TNT task, considering that the number of skipped ratings was at most two in the analyzed sample. Fourth, one participant skipped too many (18 of 60) affective ratings during the pre-TNT task. Many skipped trials during the pre-TNT affective rating task, which was administered immediately after the study and drop-off feedback cycles, indicate that the participant failed to create item-pair associations. Finally, one participant provided the same scores across all the affective ratings, and another fell asleep in the middle of the experiment; these two participants clearly did not perform the experiment appropriately. Eventually, data from 30 participants (23 males, mean age = 21.00, SD = 1.80) were analyzed. This sample size was determined based on the same pre-experimental power analysis as in Experiment 1.

Materials

In addition to the stimuli used in Experiment 1, 35 positive scene images were used as substitutes (valence: M = 7.11, SD = 0.46; arousal: M = 5.02, SD = 1.09; see Table S1 for the identifier numbers of the images). These images were randomly associated with Think or No-Think cues. Thus, the stimuli comprised 20 Think and 15 No-Think triplets and 15 Baseline pairs.

Procedure

The procedure was similar to that of Experiment 1, with three differences. First, participants were given a thought substitution instruction for the TNT task. When cues were enclosed by a green frame, participants were instructed to remember the first associates of the cues, and when cues were enclosed by a red square, they were instructed to prevent the first associates from coming to mind by recalling the second associates of the cues (substitutes). After the instruction, participants studied substitutes, which were presented on the display with corresponding Think or No-Think cues for 2 s each. In contrast to the standard thought substitution experiment, participants learned the second associates not only for No-Think cues but also for Think cues. This change made it possible to compare memory for the No-Think and Think substitutes in the following old/new recognition test in order to confirm that participants performed thought substitution. We predicted that recognition performance for No-Think substitutes should be better than that for Think substitutes, because Think substitutes did not have to be retrieved during the TNT task but should be inhibited by retrieving Think targets (as in retrieval-induced forgetting; Anderson, Bjork, & Bjork, 1994).

A second difference from Experiment 1 was a change in instructions for the intrusion ratings. To examine the intrusion frequency of the targets, participants were instructed to rate on a 3-point scale how often the first associates specifically entered awareness.

Finally, to confirm that participants retrieved the correct target with each affective rating, forced-choice cued recognition was administered at the end of each trial. As in the drop-off feedback cycles, participants were given three images: a target, a substitute, and a foil (a target from another pair). Participants were instructed to select the image that they recalled from the presented cue by clicking it. If none of the three images matched what they recalled, they could indicate that by clicking the option "None of the images above," which was displayed below the images.

Data analysis

Because of these changes, we obtained two additional behavioral measures, hit rates of substitutes in the post-TNT recognition test and hit rates in the forced-choice cued recognition test. On the hit rates for the Think and No-Think substitutes, we conducted a one-sided paired *t* test to examine whether the mean hit rate for the No-Think substitutes was higher than that for the Think substitutes. On the hit rates in the forced-choice cued recognition test, we also conducted a one-sided paired *t* test to examine whether the mean hit rate of the No-Think targets was lower than that of the Baseline targets.

The other data were analyzed in the same way as in Experiment 1, except for the valence/arousal ratings. To obtain affective ratings of target scenes, we included in the analyses only the trials on which participants correctly recognized targets in the forced-choice cued recognition test placed at the end of each affective rating trial.

Results

Intrusion proportion in the No-Think attempts

The mean intrusion proportions are shown in Figure 3A. A one-sided paired *t* test indicated that intrusion proportions did not decrease significantly from the first block to the final block, $t(29) = 0.85$, $p = .202$, $dz = 0.15$, 95% CI [-0.21, 0.51].

Recognition performance

Table S5 shows the mean hit rates for the studied scenes and the correct rejection rates for the unstudied scenes in the old/new recognition tests. Figure 3B provides the conditionalized hit rates for No-Think and Baseline scenes in the second old/new recognition test. A one-sided paired *t* test revealed that the mean hit rate was not significantly lower for No-Think targets than for Baseline targets, $t(29) = -0.83$, $p = .207$, $dz = -0.15$, 95% CI [-0.51, 0.21].

For the old/new recognition test that followed the TNT task, a one-sided paired *t* test on the mean hit rates of substitutes indicated no reliable difference between Think (M = 0.77, SD = 0.15) and No-Think (M = 0.77, SD = 0.17) substitutes, $t(29) = 0.08$, $p = .468$, $dz = 0.01$, 95% CI [-0.34, 0.37].

Table S5 also shows the mean hit rates for the forced-choice cued recognition test. A one-sided paired *t* test revealed a significantly lower mean hit rate for No-Think targets than for Baseline targets, $t(29) = -2.13$, $p = .021$, $dz = -0.39$, 95% CI [-0.76, -0.01].

Changes in affective ratings through thought substitution

Figures 3C and 3D show *Δ*valence and *Δ*arousal difference scores. One-sided paired *t* tests revealed that the difference between No-Think and Baseline scenes was significant for *Δ*valence, $t(29) = 2.03$, $p = .026$, $dz = 0.37$, 95% CI [0.00, 0.74], and marginally significant for *Δ*arousal, $t(29) = -1.43$, $p = .082$, $dz = -0.26$, 95% CI [-0.62, 0.11]. The results suggest that thought substitution alleviated both arousal and valence of aversive scenes overall.

Correlations with questionnaire scores

Figure 3E shows scatter plots and the corresponding correlations between each pair of the six scores (alleviation scores of valence/arousal and four questionnaire scores). As in Experiment 1, BDI, state anxiety, and trait anxiety were positively and moderately correlated with each other. However, rumination was correlated with BDI and state anxiety to a smaller extent than in Experiment 1. Compared to Experiment 1, both alleviation scores of valence and arousal were weakly correlated with all questionnaire scores.

Principal component analysis and regression analyses

A PCA of questionnaire scores revealed that two PCs explained over 80% of the variance. The biplot in Figure S2 shows that the four scores contributed to two PCs in a way similar to that in Experiment 1. Thus, as in Experiment 1, we defined PC 1 as anxious/depressive symptoms and PC 2 as state-trait dominance of the symptoms.

Subsequent regression analyses showed that the two PCs did not explain significant proportions of the variance of the dependent variables (all ps > .45, see Table S7).

Discussion

The aim of Experiment 2 was to examine whether thought substitution alleviates distress from aversive memories and to determine the extent to which anxious/depressive symptoms modulate this effect. Participants performed retrieval stopping during the TNT task by means a thought substitution instruction requiring them to prevent targets from coming to mind by recalling diversionary thoughts given before the task. Participants recognized fewer No-Think targets than Baseline targets in a forced-choice cued recognition test performed during the affective rating task, which ensured that thought substitution induced forgetting.

Thought substitution attenuated the distress elicited from the retrieved aversive scenes. Participants reported less arousal after the TNT task, and this reduction was greater for the No-Think targets than for the Baseline targets, although the effect size was small. Also, they reported higher valence after the TNT task, and the improvement in valence was also greater for the No-Think targets than for the Baseline targets. Unlike direct suppression, the effects of thought substitution on valence/arousal ratings were correlated weakly with anxious/depressive symptoms. These results indicate that thought substitution can reduce the distress elicited from aversive memories even for individuals with severe anxious/depressive symptoms, who are assumed to have difficulties in memory control and emotion regulation (e.g., Dieler et al., 2014; Everaert & Joormann, 2019), when they are given positive scenes as substitutes.

The effects of thought substitution on affective ratings across individuals may be attributed to interference from substitutes during affective ratings. When remembering targets to be rated from presented cues, the corresponding substitutes were also remembered because of the cue-substitute associations created through repeated substitution attempts during the TNT task. The substitute retrieval presumably distracted affective evaluation of target memories during affective ratings. Like target retrieval, substitute retrieval also supposedly caused emotional responses, which biased the affective evaluation. Because the substitutes were comfortable scene images, the interference effect of substitutes resulted in affective ratings for target retrieval that were higher in valence and lower in arousal. According to this account, affective properties of substitute materials are critical to the effect of thought substitution. Indeed, material properties seem related to the size of effects on valence and arousal. In the present study, substitutes were much higher in valence than No-Think targets, but not so different in arousal. Consistent with this property, the absolute value of the effect size was smaller for arousal (dz = -0.26) than for valence (dz = 0.37). This finding partly supports the interference account of the effects of thought substitution on valence and arousal.

The correlation results indicate that the effects on affective ratings were not compromised by anxious/depressive symptoms. The results are apparently inconsistent with previous findings of cognitive control deficits related to these symptoms. For example, previous TNT studies demonstrated that dysphoric participants exhibited less forgetting through thought substitution than non-dysphoric counterparts (Noreen & Ridout, 2016a, 2016b). Indeed, in the present study, small to medium negative correlations between the size of forgetting in cued recognition and anxious/depressive symptoms were observed (Figure S5). This discrepancy between the effects of thought substitution on memory versus emotion does not contradict the interference account for the effect of thought substitution. Repeated thought substitution presumably created association between cues and substitutes, which made it more likely that substitutes were retrieved with targets from cues during the affective ratings. Even if anxious/depressive individuals failed to forget or impair the target representations by the interference from substitutes because of their cognitive dysfunction, substitutes retrieved together still might have distracted and biased evaluation of the targets.

Although the present experiment provided evidence for effects of thought substitution on negative scene memories and emotional reactions to their retrieval, additional results should also be noted. First, the proportion of intrusion trials was constant at a medium level (approximately 50%) across the TNT blocks. Although attempts to retrieve substitutes reduced intrusion of target memories relative to attempts to retrieve target memories, the proportion of intrusions did not decline with repeated thought substitution. This may have been attributable to the retrieval process required for thought substitution, contrary to direct suppression. When participants retrieved substitutes corresponding to the presented cues, they may have mistakenly produced target memories, due to the strong associations between targets and cues that were formed during the drop-off/feedback cycles. Even if repeated thought substitution created stronger associations between cues and substitutes, it could not completely replace the cue-target association. Thus, the intrusion of targets occurred constantly throughout the TNT task. The present experiment is the first attempt to measure subjective intrusion of targets during thought substitution.

Elaboration of the differences between the two strategies is a worthwhile topic for future examination.

Second, the hit rate of Think substitutes was not lower than that of No-Think substitutes. This result is inconsistent with our prediction. This may have been attributable to an initial weak association between cues and substitutes. We predicted that Think substitutes would be inhibited in retrieving targets, resulting in lower hit rates, such as those found in retrieval-induced forgetting. However, to produce an effect like retrieval-induced forgetting, associations of substitutes with cues should be stronger than associations of substitutes with targets (the strength-dependent property of retrieval-induced forgetting; Anderson, 2003). In the present experiment, this property was absent because substitutes seemed to be more weakly associated with cues than with targets after a few study sessions. Therefore, the recognition of Think substitutes was preserved at the same level as that of No-Think substitutes.

General Discussion

A growing number of TNT studies in recent years have examined effects of retrieval stopping on emotion (e.g., Gagnepain et al., 2017). It is notable that previous studies have focused on the effects of retrieval stopping on emotion elicited by external aversive stimuli (exogenously elicited emotion), although emotion can readily be evoked by the retrieval of aversive memories (endogenously elicited emotion). Furthermore, previous studies employed only direct suppression as a retrieval stopping strategy, which is only one of two stopping strategies (Benoit & Anderson, 2012). Thus, the present study examined the effects of both retrieval stopping strategies, direct suppression and thought substitution, on endogenously elicited emotions, as well as their relationship to anxious and depressive symptoms. In Experiment 1, direct suppression significantly alleviated arousal across participants, but it did not improve valence. In addition, the effects of direct suppression on valence and arousal were modulated by anxious/depressive symptoms. Specifically, individuals with more severe anxious/depressive symptoms exhibited smaller effects on both valence and arousal. Experiment 2 showed that thought substitution alleviated negative valence and high arousal across participants, and this effect was not modulated by anxious/depressive symptoms. The differences in results were confirmed by integrated regression analyses of the data of the two experiments (see the Supplementary Analysis).

The different characteristics of the effects of the two strategies on affective ratings can be attributed to distinct mechanisms that underlie these strategies (Benoit & Anderson, 2012). Direct suppression involves inhibitory control, which impairs memory traces. Impaired memory representations presumably elicit emotion to a lesser extent than intact representations when they are retrieved. Furthermore, according to the parallel regulation hypothesis of memory and emotion (Gagnepain et al., 2017), inhibitory control directly regulates emotion during direct suppression attempts, which also contributes to attenuated distress from aversive memories at later retrieval (i.e., post-TNT affective rating). Through these possible mechanisms, direct suppression attenuates distress from aversive memories. However, the effects of direct suppression are compromised by anxious/depressive symptoms. Because these symptoms are associated with deficits in cognitive control, including memory inhibition (e.g., Stramaccia et al., 2020), the core component of direct suppression, inhibitory control, is not exerted successfully, resulting in smaller (or reversed) effects.

In contrast, thought substitution mainly involves selective retrieval of substitutes. Repeated retrieval of substitutes during the TNT task creates cue-substitute associations, which make it more likely that substitutes are retrieved from cues. Due to the association, substitutes are retrieved when targets are retrieved from cues. The corresponding substitute retrieval distracts the evaluation of emotion elicited by target retrieval during affective ratings. Specifically, emotion elicited by substitute retrieval biases the evaluation. Therefore, thought substitution reduces distress during target retrieval at least when the substitute memories are comfortable ones. Even if anxious/depressed individuals have cognitive deficits, they might be able to create cue-substitute associations and learn to retrieve substitutes from cues through repeated substitution attempts during the TNT task. The associations initiate the retrieval of substitutes during affective ratings as mentioned above, which distracts and biases affective evaluation of target memories. Thus, the effect of thought substitution on affective ratings is not modulated by anxious/depressive symptoms. We should note, however, that it is unclear whether the effects would still be observed when the substitutes are negative or neutral, or when participants generate substitutes on their own. Although the present interference account predicts smaller effects in the first case, further investigation is required. In addition, although we assumed here that interference from substitutes reduced distress from aversive memories regardless of anxious/depressive symptoms, it is still possible that the similar results of affective ratings emerged from different mechanisms of thought substitution depending on the severity of the symptoms. This point should be scrutinized in future studies.

We observed lower hit rates in an old/new recognition (Experiment 1) and forced-choice cued recognition (Experiment 2). These findings suggest that consistent with previous studies both retrieval stopping strategies caused forgetting of target memories. However, the observed effects were smaller than those in previous studies probably due to the difference in test methods. Unlike in the current study, memory performance is assessed by recall tests in the standard TNT studies. The reason that recognition tests were employed in the current study was that materials used for targets (i.e., images) were difficult to assess with recall tests. In addition to the difference in test methods, different learning criteria for drop-off test cycles (test and feedback cycles in the standard procedure) likely contributed to the smaller effect. While most previous studies required 50 % correct recall, the current study required participants to recognize correct targets for all the pairs (i.e., 100 % correct recognition) because it was desirable for participants to remember as many targets as possible in the affective rating task for the current research purpose. These two major changes in procedures presumably caused a ceiling effect in memory performance. Although it is somewhat problematic to test data with a ceiling effect by *t* test, the lower hit rate of the No-Think items indicates that No-Think attempts cause memory impairment.

In conclusion, the present study has demonstrated that direct suppression and thought substitution can reduce distress from aversive memories in different ways: by inhibitory control and by interference. This difference was evident in the relationships with anxious/depressive symptoms. It is widely known that retrieval stopping contributes to prevention of mental disorders such as post-traumatic stress disorder (Mary et al., 2020). The present findings suggest that prevention through retrieval stopping involves not only impairment of aversive memories but also attenuation of the emotion elicited by those memories.

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Declaration of Interest Statement

We have no conflicts of interest to disclose.

Author Contributions

S.N. and S.S. contributed to the study design. S.N. performed the experiments and analyzed the data. S.N. drafted the manuscript and both authors revised the manuscript. Both authors approved the final manuscript for submission.

Open Practices Statements

The data and R scripts for all experiments are available at Open Science Framework (https://osf.io/nep93/) and neither experiment was preregistered.

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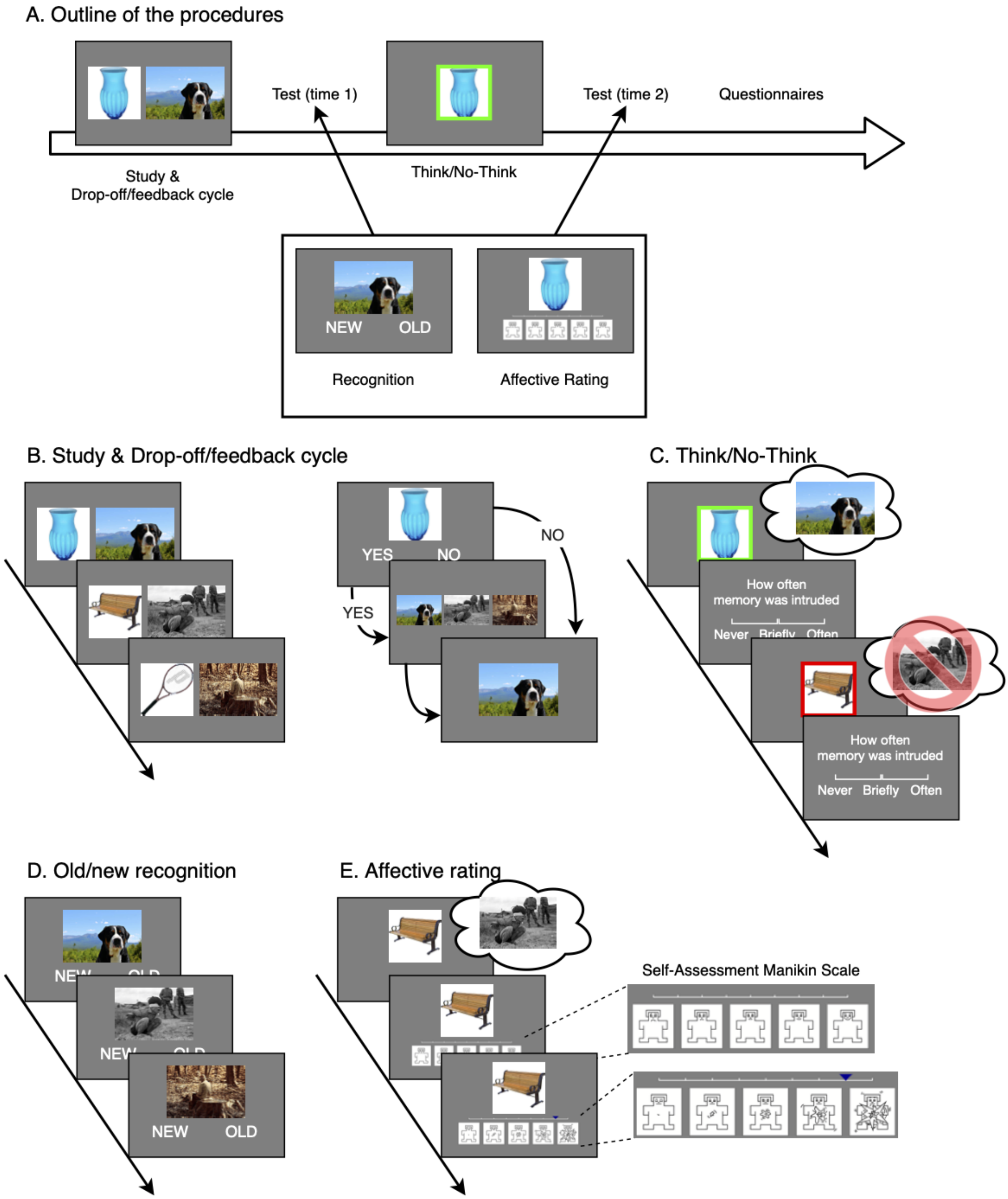
Figures

Figure 1

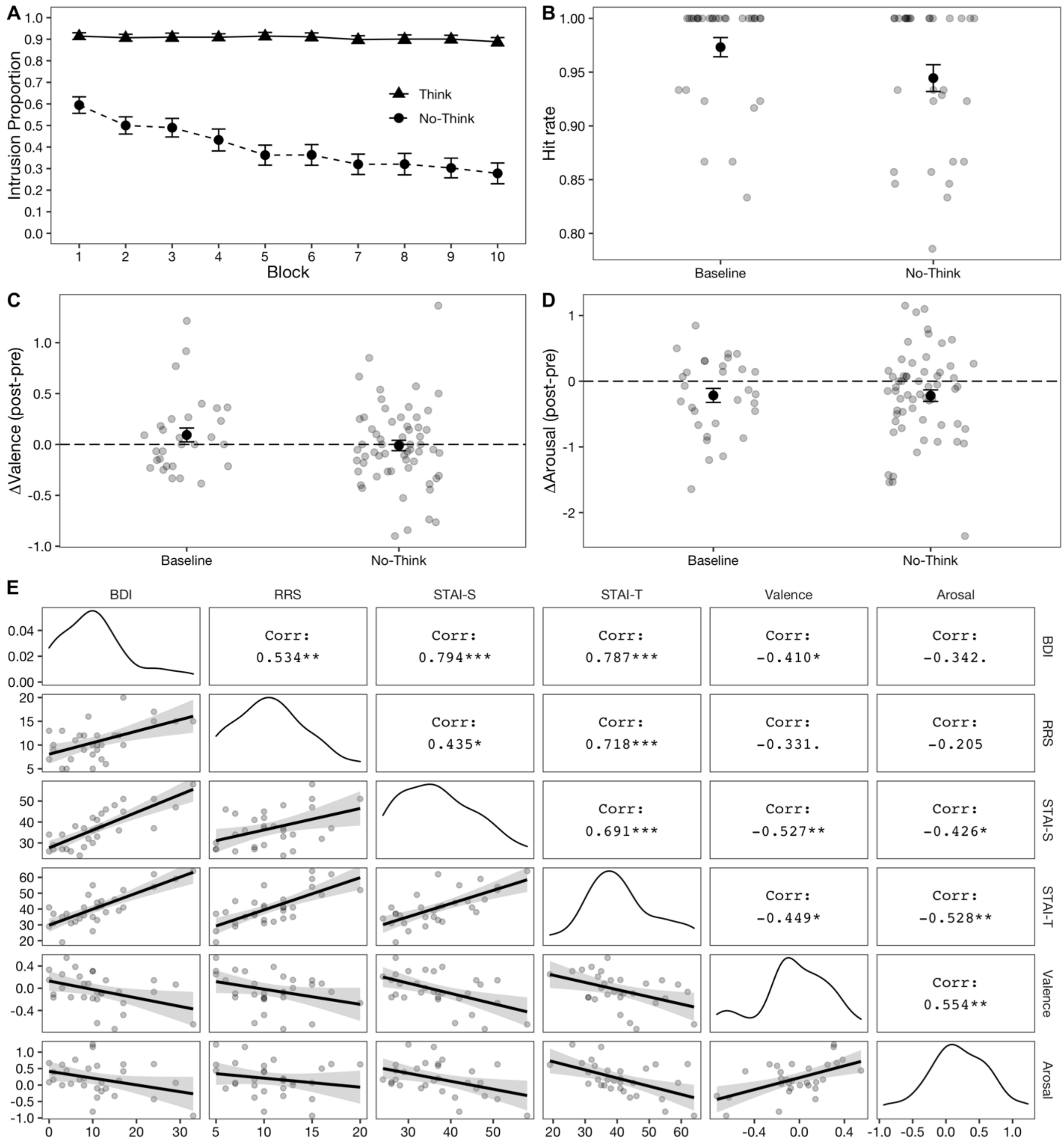
Outline of Procedures and Trial Sequences of Each Phase in Experiment 1



Note. A. The eight phases of the experiment: encoding, drop-off/feedback cycles, recognition (time 1), affective rating (time 1), Think/No-Think task, recognition (time 2), affective rating (time 2), and questionnaires. B. During the study phase, object-scene pairs were presented for 5 s each. After all pairs were presented once, participants performed drop-off feedback cycles. Each trial began with a cue presentation. Participants indicated whether they could retrieve the associated scene. If they selected “yes,” they were required to select the associate from three options: the correct scene and two incorrect scenes paired with other objects. After selection, the correct target was presented on the display as feedback, regardless of response accuracy. If participants selected “no” after the cue, they were shown the correct target. C. During the TNT task, participants engaged in “Think” or “No-Think” as instructed, depending on the color of the frame surrounding the cue image. At the end of each trial, the participants indicated how often the target came into their awareness. D. During the old/new recognition test, participants indicated whether they had seen a scene image on the display in the experiment. E. Each trial of the affective rating task began with a cue presentation. Participants retrieved the associated scene for 5 s then rated the valence and arousal that they felt in remembering the scene using Self-Assessment Manikin rating scales below the cue.

Figure 2

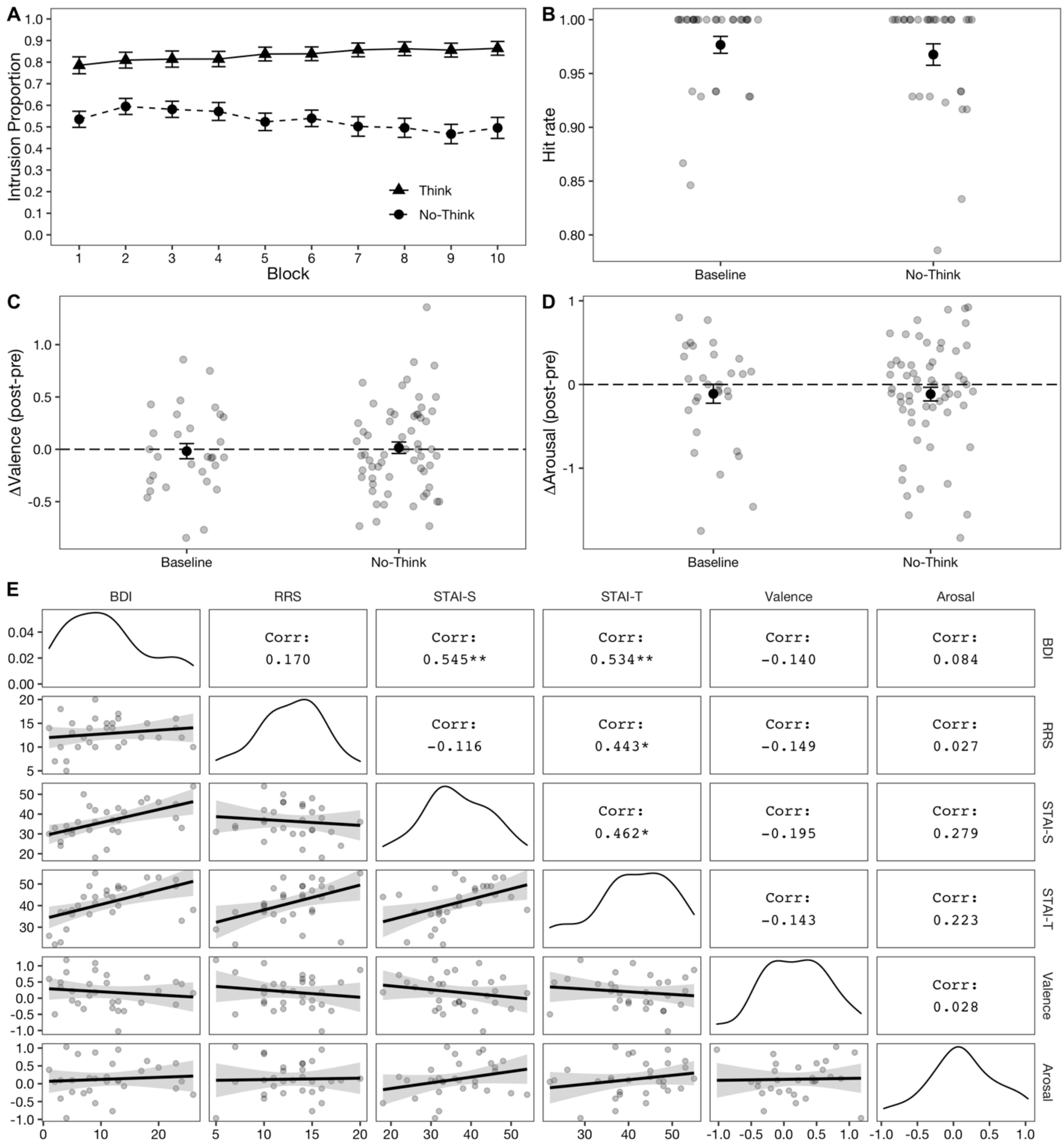
Behavioral Measures and Correlations with Questionnaire Scores in Experiment 1



Note. A. Mean intrusion proportions of No-Think targets and successful retrieval proportion of Think targets as a function of TNT blocks. Error bars represent standard errors of the mean. B. Individual (gray dots) and mean (black dots) conditionalized hit rates of No-Think and Baseline targets for old/new recognition after the TNT task. C. Individual (gray dots) and mean (black dots) pre-post differences in valence ratings for No-Think and Baseline target retrieval. D. Individual (gray dots) and mean (black dots) pre-post differences in arousal ratings for No-Think and Baseline target retrieval. E. Matrix of plots describing relationships between pairs of effects on arousal/valence ratings and four questionnaire scores. Scatterplots of each two of the measures are presented in the lower area. Smoothed histograms illustrating density estimates are shown in the diagonal area. Correlations corresponding to the scatterplots in the lower area are presented in the upper section. BDI = Beck Depression Inventory. RRS = ruminative response scale. STAI-S = state anxiety. STAI-T = trait anxiety. For all figures, error bars represent standard errors of the mean.

Figure 3

Behavioral Measures and Correlations with Questionnaire Scores in Experiment 2



Note. A. Mean intrusion proportions of No-Think targets and successful retrieval proportion of Think targets as a function of TNT block. B. Individual (gray dots) and mean (black dots) conditionalized hit rates for No-Think and Baseline targets on old/new recognition after the TNT task. C. Individual (gray dots) and mean (black dots) pre-post differences in valence ratings for No-Think and Baseline target retrieval. D. Individual (gray dots) and mean (black dots) pre-post differences in arousal ratings for No-Think and Baseline target retrieval. E. Matrix of plots describing relationships between pairs of effects on arousal/valence ratings and four questionnaire scores. Scatterplots of each two of the measures are presented in the lower area. Smoothed histograms illustrating density estimates are shown in the diagonal area. Correlations corresponding to the scatterplots in the lower area are presented in the upper section. BDI = Beck Depression Inventory. RRS = ruminative response scale. STAI-S = state anxiety. STAI-T = trait anxiety. For all figures, error bars represent standard errors of the mean.