Inhibitory effects of thought substitution in the think/no-think task: Evidence from independent cues

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Abstract

When people try not to think about a certain item, they can accomplish this goal by using a thought substitution strategy and think about something else. Research conducted with the think/no-think paradigm indicates that such strategy leads subsequently to forgetting the information participants tried not to think about. The present study pursued two goals. First, it investigated the mechanism of forgetting due to thought substitution, contrasting the hypothesis by which forgetting is due to blocking caused by substitutes with the hypothesis that forgetting is due to inhibition (using an independent cue methodology). Second, a boundary condition for forgetting due to thought substitution was examined by creating conditions under which generation of appropriate substitutes would be impaired. In two experiments, participants completed a Think-NoThink task (Anderson & Green, 2001) under thought substitution instructions in which either words or pseudo-words were used as original cues and memory was assessed with original and independent cues. The results revealed forgetting in both original and independent cue tests, supporting the inhibitory account of thought substitution, but only when cues were words, and not when they were non-words, pointing to the ineffectiveness of a thought substitution strategy when original cues lack semantic content.

Inhibitory effects of thought substitution in the think/no-think task: Evidence from independent probes

It has been long recognized in the memory literature that an effective memory system needs to be equipped not only with mechanisms supporting encoding and retrieval operations but also with mechanisms that could limit access to information that is irrelevant, outdated or somehow disruptive to efficient cognitive functioning (cf. Anderson, 2003). Given the negative effects of, for example, retrieval interference (Anderson & Neely, 1996) and spontaneous retrieval of emotionally disturbing memories (e.g. Rubin, Berntsen, & Bohni, 2008), it is vital to investigate the mechanisms by which people can stop remembering unwanted or unnecessary information. Recent empirical developments suggests that one way in which such forgetting can be induced is by asking people to simply think of something else. For example, asking people to engage in a simple imagination task leads to impaired memory for a list of words that they learned just before the completion of this task (Sahakyan & Kelley, 2002). Also when people are asked specifically not to retrieve some information, they can accomplish this by thinking about something else instead, which as a consequence also leads to forgetting information they were trying not to retrieve (Hertel & Calcaterra, 2005; Racsmány, Conway, Keresztes, & Krajcsi, 2012). In the present study we focus on this later observation and we address two questions related to it. First, we ask about the mechanism that leads to forgetting when people use thought substitutes in order to avoid retrieval. Second, we ask about the effectiveness of the strategy of using thought substitutes in the face of retrieval cues which vary in the amount of their semantic content.

The thought substitution strategy has been examined in the context of a paradigm designed to investigate forgetting due to voluntary retrieval avoidance. In this so called *think/no-think* (TNT) paradigm (Anderson & Green, 2001), participants are first asked to

learn pairs of stimuli, usually pairs of words, composed of a cue and a target. The learning proceeds in study-test cycles until participants reach a certain criterion. Subsequently, in the main phase of the procedure, participants are presented with some of the cues and asked to either remember a target (*Think condition*) or to prevent a target from entering the mind (*No-Think condition*). In the final test, participants' memory for targets assigned to the Think and No-Think conditions is compared to memory for baseline targets that had been initially learned but for which the cues were not presented in the think/no-think phase of the procedure. Studies have found that while memory for targets in the Think condition is better than baseline memory, memory for targets in the No-Think condition is worse than baseline, indicating that the targets in this condition are forgotten due to repeated suppression of retrieval (e.g. Anderson & Green, 2001; Hanslmayr, Leipold, & Bäuml, 2010; Anderson, Reinholz, Kuhl, & Mayr, 2011; Joormann, Hertel, Lemoult, & Gotlib, 2009; Kim, Yi, Yang, & Lee, 2007; Hanslmayr, Leipold, & Bauml, 2010; Joormann, Hertel, Brozovich, & Gotlib, 2005; Lambert, Good, & Kirk,2010; but see Bulevich, Roediger, Balota, & Butler, 2006; for a complete review see Anderson and Huddleston, 2012).

The task of stopping retrieval of targets in the No-Think condition can be achieved in various ways (cf. Anderson & Green, 2001). One of them is the strategy of using thought substitutes which is the focus of the present study. Hertel and Calcaterra (2005) examined this strategy by contrasting two groups in the TNT paradigm. Participants in the 'aided' group were given substitute words that they were instructed to recall in lieu of the targets form the No-Think condition. Participants in the unaided group were not presented with such substitute words and were simply instructed to try not to retrieve targets in the No-Think condition. Hertel and Calcaterra found that below-baseline forgetting in the No-Think condition occurred only when participants were either instructed to recall substitutes for the targets assigned to the No-Think condition (i.e. in the aided group) or when they

spontaneously used this very strategy in the unaided group (as assessed by a post-experimental questionnaire). Subsequent studies supported the role of the thought substitution strategy in creating below-baseline forgetting in the TNT task (e.g. Racsmány et al., 2012), although forgetting has also been found for participants who do not engage in thought substitution strategy (e.g. Benoit & Anderson, 2012; Bergström, de Fockert, & Richardson-Klavehn, 2009).

Forgetting due to repeated engaging in thought substitution can be caused by two mechanisms. First, such forgetting can reflect blocking the access to targets caused by substitute words, which are associated to the same cues by virtue of their repeated retrieval. Every time a cue in the No-Think condition is used to access a substitute, an associative link between the cue and the substitute is strengthened. When later the same cues are used to access targets, the substitutes can come to mind instead of the original target, and after several unsuccessful attempts to reach the original target now blocked by a substitute, participants may abandon memory search (Rundus, 1973). Second, repeated retrieval of substitutes can lead to inhibition of targets. The inhibitory framework of forgetting (Anderson, 2003) postulates that when two different items are associated to the same cue, an attempt to retrieve one of them (a word substitute in this case) is hindered by competition from the other item (a target word in this case). To resolve this competition, an inhibitory mechanism needs to be recruited which suppresses the memory representation of the competitor (the target word). This inhibition has lasting effects, leading to forgetting of competitors that can be detected on a subsequent test.

A common method to disentangle the blocking and inhibitory mechanisms of forgetting is to use an independent probe methodology (e.g. Anderson & Green, 2001). Because the blocking hypothesis postulates that forgetting occurs when attempted retrieval of targets is cued with the same cue to which substitutes became strongly associated, it

straightforwardly predicts that using different cues should allow for circumventing blocking and successful retrieval of targets. The blocking hypothesis thus predicts that providing independent cues, that is cues that have direct association to the correspondent target and that have not direct association to any alternate competing response to the target, in the think/no-think phase of the procedure should eliminate forgetting observed for targets in the No-Think condition. In contrast, the inhibitory hypothesis assigns forgetting to suppression of the memory representations of the targets themselves. It thus predicts forgetting also when independent cues are presented in the final test.

Only two studies have been conducted that employed independent cues and assessed forgetting when people were asked to use the thought substitution strategy: Anderson and Beinot, (2012) and Bergström et al., (2009). In the study by Bergström et al, similarly to the study by Hertel and Calcaterra (2005), two groups were contrasted, one in which the strategy of thought substitution was induced and another in which participants were asked to try to avoid thinking of the targets in the No-Think condition. In two final tests both original cues and independent cues were employed. Bergström et al. found forgetting in both groups when the original cues were provided. However, the thought suppression group did not show forgetting when independent cues were presented. The researchers concluded that forgetting due to intentional stopping of retrieval was produced by inhibitory processes but that forgetting due to the use of thought substitutes was caused by blocking rather than by inhibition. However, as acknowledged by the authors themselves, the results from the thought substitution group are surprising if one considers them against the whole background of research in memory inhibition. Specifically, results obtained from the so called *retrieval practice paradigm* suggest that repeated retrieval of substitutes should induce inhibition for items related to the cues used during retrieval. For example, Anderson and Bell (2001) used the retrieval practice paradigm and clearly demonstrated that repeated retrieval of a target

episodically associated to a cue led to forgetting of other targets episodically related to the same cue and that this type of forgetting was also cue-independent, involving then the mechanism of inhibition.

Benoit and Anderson (2012) also tried to contrast the thought substitution strategy with direct suppression by using independent cues. This experiment was divided in 4 phases: a) a typical study phase; b) a practice phase where all the participants were trained to engage in direct suppression as well as in thoughts substitution; c) the critical suppression phase, where there were two experimental conditions: thoughts substitution and direct forgetting; 4) the final memory test. The results showed that with same probes as well as with independent probes, baseline items (i.e. target not re-cued during the suppression phase) were better recalled than items in the no-think condition. Interestingly, and in contrast with the results of Bergström et al. (2009), they found similar TNT forgetting effects for both direct suppression and thoughts substitution groups, although they engaged different neural circuits.

In the two experiments reported here we tried to clarify possible reasons for the discrepant results regarding thought substitution. In Experiment I we explored whether using thought substitutes in the TNT paradigm leads to forgetting when the original study cues are presented in the final test, but not when independent cues are used (as the blocking hypothesis postulates) or whether thought substitution leads to parallel effects in both tests (as the inhibitory hypothesis postulates). With this purpose in mind we introduced two conditions in which participants were instructed to try not to think about the targets by using substitutes. However in one condition thought substitution was facilitated by using words as cues, while in the other condition the use of the strategy was made difficult by presenting pseudo-words as cues. The second experiment was aimed at disentangling the reasons that can make more or less effective the thought substitution strategy, by manipulating the degree

of learning of the original cue-target pairs and introducing a questionnaire to assess the relation between the target and thought substitutes.

Experiment 1

In Experiment 1 we explored the processes underlying forgetting in the TNT procedure when participants are instructed to use substitute thoughts to avoid thinking about the target. In order to maximize the likelihood of recruiting inhibitory mechanisms, we set the learning criterion in the study phase to 100% correct. This procedure should enhance the likelihood of getting intrusive memories in the No-Think condition, which would be more likely to require inhibition to aid the successful retrieval of thought substitutes.

A second aim of the present study was to understand the constraining conditions for the use of the thoughts substitution strategy by providing a condition (i.e. pseudo-words) where a thought substitution strategy may no longer be effective in producing forgetting. Previous investigations on the thought substitution strategy used two different procedures. The procedure used by Hertel and Calcaterra (2005) provided participants with specific substitutes (aids) that were related to the cues and thus could be easily retrieved in lieu of targets. Although such a procedure provides the experimenter with substantial control over participants' behavior in the task, it also limits the generality of the findings. The question is whether specific substitutes have to be provided to make a thought substitution strategy effective. The results of the second type of procedure, implemented by Bergström et al. (2009), indicate that it is not the case. Bergström et al. did not provide their participants with specific substitutes and instead simply instructed them to think "of other words associated with the hint word in order to block the response". The results obtained by Bergström et al. indicate that even such general instructions can induce forgetting, at least in the original cue test.

The present study attempted to replicate forgetting obtained with general instructions for thought substitution without providing specific substitutes and it also sought to establish if the nature of the cues can affect the effectiveness of the thought substitution strategy. When participants are not given specific substitutes, they need to use information contained in the cue to produce their own substitutes. It seems intuitive that such substitutes should generally be related to the meaning of a cue. We reasoned thus that if cues were meaningless, then participants could encounter problems in generating substitutes that they would be able to repeatedly retrieve during the No-Think trials. This in turn would reduce the effectiveness of the thought substitution strategy, leading to reduced forgetting. In the present study we tested this hypothesis by providing two types of cues. The word cues were the same as in the standard version of TNT task. The novel condition used pseudo-words as cues. Pseudo-words lack semantic information and thus generating substitutes for such cues should be relatively difficult, leading to a less effective implementation of the thought substitution strategy. We predicted thus that forgetting should occur for word cues, in either the original cue test alone or both the original cue and independent cue tests (if the effect is due to inhibition), but it should be reduced or eliminated for pseudo-word cues.

Method

Participants

62 participants (31 males and 31 females, mean age = 24.66; range 21-38) volunteered to take part in the experiment.

Materials and design

One set of word-word pairs and one set of pseudoword – word pairs were created by initially selecting 72 Italian words. The 72 words were then divided in two sets of 36 words each.

Words in the two sets were matched in length (up to 6 letters) and frequency. Words in the first set were used as targets in the pairs. The other set contained words used as cues. Eighteen of the cue words were then turned into legal pseudo-words by replacing two letters of the words (e.g. ELICA (word) -> ELOTA (pseudo-word)) without changing the initial bigram. The eighteen cue words from which the pseudo-words were created were matched with the remaining 18 cue words in length, frequency and initial bigram (e.g. CARRO - CANTO). Eighteen cue-target word-word pairs and eighteen cue-target pseudoword-word pairs were then created. Although the idea that meaningless cues can fail to produce forgetting is reasonable, it needed to be proved. To confirm that the legal pseudo-words produce significantly less associates than words, 20 Italian participants (age: M= 28.35, DS=4.77; 11 males) were presented with the 18 word cues and the 18 pseudo-word cues in a mixed list. The order of items in the list was random, and different for each participant. Words were presented one at a time, on a card, and participants were asked to produce and write down as many associations as they could within 5 sec time. The results showed that participants produced significantly more associates to words (M = 3.55) than to non-words (M = 2.25); t (19) = 6.11 p<.001.

In no pair the target word had a semantic or phonological relationship with the cue. For each target word a short definition was created to be used as a probe in the independent probe test. For example, if the target word was *"computer"* the short definition used as an independent probe was *"Used to surf the Internet"*.

The main study conformed to a 2 (cue: Word vs. Pseudo-word) x 3 (TNT condition: Baseline, Think, No-Think) within-participants design. The dependent measures were recall rate on the same probe test and recall rate on the independent probe test.

Procedure

The procedure was divided into three main phases: study phase, think/no-think phase and test phase.

Study phase: Participants were instructed to learn the 36 cue-target pairs which were presented on a computer screen one at a time for 5 sec each. The 36 pairs were divided into six blocks and each block was repeated four times. The order of the blocks was randomized across participants but it was fixed for each participant. After the presentation participants received the first cued-recall test. Cues were presented one at a time on a computer screen, and participants were instructed to recall the target that had been presented with each cue. This task was self-paced and the experimenter recorded the responses and controlled the presentation of the cues. Participants who recalled correctly all the targets advanced to the next phase of the experiment. If participant failed to recall any of the targets, all 36 cue-target pairs were again presented once and a cued recall test followed. This procedure was repeated until all participants recalled correctly all of the targets (100% correct).

Think/No-think phase: During this phase, 24 cues (12 words and 12 pseudo-words) were presented one at a time in the centre of the computer screen, for 3 sec each. The remaining 12 cues were not presented during the think/no-think phase and were later used to create a Baseline condition. Twelve of the presented cues (six words and six pseudo-words) were shown in green font. Participants were instructed that for cues presented in green they should covertly retrieve the appropriate target (Think condition). The other 12 cues (six words and six pseudo-words) were shown in red font. Participants were instructed that for cues presented in red font they should avoid thinking about the target associated with that cue (No-Think condition). They were further instructed to use a thought substitution strategy for red-font cues and to think about anything that came to their mind in response to these cues in order to divert their thoughts away from the targets. Each of the 24 cues used in this phase

was presented 12 times, for a total of 288 trials. The assignment of cues to the three conditions (Think, No-Think and Baseline) was counterbalanced across participants.

Final recall: The final phase of the experiment consisted of two separate recall tests. For the original cue test participants were presented with all cues (18 words and 18 pseudo-words) used in the study phase and associated with targets from three different experimental conditions (12 targets each for Baseline, Think, and No-Think conditions). Cues were presented one at a time, in black font together with the first letters of the targets. For the independent cue test participants were presented with the short definitions created for each target, together with the first letters of these targets (see Anderson, 2003, for arguments for using first letters in such tests). For both tests participants were asked to say aloud the appropriate target from the study phase when presented with the cue, and the responses were coded by the experimenter who also controlled the presentation of the cues. Order of tests (original cue test first, independent cue test first) was counterbalanced across participants.

Finally, the participants filled out a strategy questionnaire (see table 2) to assess whether they followed the instruction of thoughts substitution, if they did find substitutions, and to measure their confidence on succeeding in using the strategy.

Results

Analyses focus on the comparison between recall performance in the Baseline and No-Think conditions. The performance in the Think condition was at ceiling across conditions and is not discussed further. Mean correct recall across conditions can be found in Table 1.

Original cue test. A 2 (TNT condition: Baseline vs. No-Think) x 2 (cue: Word vs. Pseudo-word) ANOVA on proportion of correctly recalled target words in the same probe task revealed a main effect of condition [$F(1,61) = 4.29$, $p = .043$, $\eta^2 = .066$], demonstrating that recall was higher in the Baseline than in the No-Think condition. Importantly, this main

effect was qualified by a significant interaction [$F(1,61) = 7.76$, $p = .007$, $\eta^2 = .11$]. The interaction emerged because recall was worse in the No-Think condition compared to Baseline condition when words were used as cues ($t(61) = 3.18$, $p < .002$) but there was no difference between conditions when pseudo-words served as cues ($t(61) = -.39$, $p < .70$).

Independent cue test. A 2 (TNT condition: Baseline vs. No-Think) x 2 (cue: Word vs. Pseudo-word) ANOVA on proportion of correctly recalled target words in the independent probe task revealed only a significant interaction [$F(1,61) = 4.50$, $p < .04$, $\eta^2 = .07$]. The interaction emerged because recall was worse in the No-Think condition compared to the Baseline condition when words served as cues ($t(61) = 2.38$, $p = .021$) but there was no difference between conditions when pseudo-words were used ($t(61) = -.60$, $p < .55$).

Strategy questionnaire. The results of the strategy questionnaire showed that the participants followed the instructions. Specifically, to the question "did you successfully manage to avoid thinking about the targets?", 43% of the participants responded "at least in 50% of the cases"; 27.7% answered "at least in the 75% of the cases" and 14.4% answered "in 100% of the cases". To the question "For how many words (or no words) did you manage to avoid thinking of the word associated with it?" 34.6% of the participants responded "at least in 50% of the cases"; 37.8% answered "at least in 75% of the cases" and 14% answered "in the 100% of the cases". To the question "Which kind of strategy did you predominantly use when trying to avoid the associate word?", 77.2% of participants answered "I tried to associate something else to each word" , and 14% "I tried to keep my mind clear".

Discussion

The results of Experiment 1 suggest that thought substitution is a strategy that produces forgetting with both original and independent cues when the conditions of the experiment

make thought substitution possible. Forgetting appeared when words were presented as cues and participants could use them to generate substitutes, but not when pseudo-words were used as cues and thought substitution was harder to implement. Importantly, results from Experiment 1 indicate that forgetting by thought substitution is cue independent (TNT effects appeared with same and different cues) as predicted by the inhibitory account. These results replicated those obtained by Benoit and Anderson (2012), who showed that thought substitution can produce forgetting with independent probes. Our results differed from those obtained by Bergstrom et al (2009). In their study thought substitution produced forgetting only in the cue-dependent test, a result consistent with the blocking explanation of the effect.

The discrepancy between our results and those by Bergström et al (2009) can be due to our learning criterion of the original cue-target pairs being very high (100%) compared to theirs (50%), thus making our target items stronger competitors at retrieval. To assess whether learning of the original pairs might explain the different results, we designed a second experiment that in which pairs were learned to either a 50% criterion (as in Bergström et al, 2009) or to a 100% criterion, as in our study 1.

Experiment 2

In Experiment 2, the same materials and the same procedure were used as in Experiment 1, but we split the sample in two conditions. In one condition, the participants moved to the suppression phase just after reaching a criterion of 50 % correct recall (similar to the experiments by Bergström et al, 2009). In the other condition, the participants moved to the suppression phase when they correctly recalled 100% of cue-target pairs (similar to our Experiment 1). To gain a better understanding of the role of the semantic relationship between the target and the substitute thoughts, we introduced a post-experimental check in which we assessed the substitutes participants used during the suppression phase and their

degree of relationship with the to-be-suppressed items. Knowing this relationship is important given that Benoit and Anderson (2012) suggested that the effectiveness of thought substitution depends on the relatedness between the unwanted memory and their substitutes. As shown in the literature on retrieval induced forgetting (Anderson, Green & McCulloch, 2000; Goodmon & Anderson, 2011), a strong relation between the practiced memory and the competitor can reduce forgetting. Then, in the TNT paradigm, the different results obtained when thought substitution is adopted can also be explained by the degree of the semantic relationship between the to-be-suppressed item and its substitute thought. A stronger relationship would decrease forgetting.

The level of semantic associations between substitution thoughts, the original cues and targets was assessed in Experiment 2 by asking participants to write down the substitute thought that they used for each cue. This post manipulation check is similar to that used by Benoit and Anderson (2012).

Method

Participants

48 participants (22 males and 26 females, mean age = 23.19; range 19-28) volunteered to take part in the experiment.

Materials and design

The material was identical to the material used in the Experiment 1. The main study conformed to a 2 (cue: Word vs. Pseudo-word) x 2 (TNT condition: Baseline, Think, No-Think) x 2 (level of training: 50% of correct recalled after the training, 100% of correct recalled after the training) mixed design. The dependent measures were recall rate on the same probe test and recall rate on the independent probe test.

Procedure

The procedure was exactly the same of the Experiment 1, with just two differences: 1) The participants were randomly assigned to two training groups. Half of the participants started the Think/no-Think phase if they correctly recalled 50% of the cue-target associations. The other half started the Think/no-Think phase only when they correctly recalled 100% of the cue-target associations. 2) At the end of the experiment, before the strategy questionnaire (i.e. manipulation check) the participants wrote the words that they used as diversionary thoughts.

Results

Similarly to Experiment 1, in Experiment 2 the analyses focused on the comparison between recall performance in the Baseline and No-Think conditions. The performance in the Think condition was at ceiling across conditions and is not discussed further. Mean correct recall for all conditions can be found in Table 1.

Original cue test. A 2 (TNT condition: Baseline vs. No-Think) x 2 (cue: Word vs. Pseudo-word) x 2 (50% vs. 100% of training) ANOVA on proportion of correctly recalled target words in the same probe task revealed a main effect of TNT condition [$F(1,46) = 9.01$, $p = .004$, $\eta^2 = .16$], showing that recall was higher in the Baseline than in the No-Think condition. This main effect was, however, qualified by a significant interaction between TNT condition and word type [$F(1,46) = 21.8$, $p = .001$, $\eta^2 = .32$]. The interaction emerged because recall was worse in the No-Think condition compared to the Baseline condition when words were used as cues ($t(47) = 6.62$, $p < .001$) but there was no difference between conditions when pseudo-words served as cues ($t(47) = 1.28$, $p < .20$). The main effect of word type was also significant [$F(1,46) = 4.4$, $p = .048$, $\eta^2 = .086$], showing less forgetting overall in the pseudo-

word condition. There was no effect of training condition, neither any interaction between training condition and the other independent variables.

Independent cue test. A 2 (TNT condition: Baseline vs. No-Think) x 2 (cue: Word vs. Pseudo-word) x 2 (50% vs 100% of training) ANOVA on proportion of correctly recalled target words in the independent probe task revealed a significant interaction between TNT condition and word type [$F(1,46) = 11.00$, $p < .002$, $\eta^2 = .19$]. The interaction emerged because recall was worse in the No-Think condition compared to the Baseline condition when words were used as cues in the study and think/no-think phases of the experiment ($t(47) = -3.2$, $p = .002$) but there was no difference between conditions when pseudo-words served as cues ($t(47) = .72$, $p < .47$). Interestingly, we found a triple interaction [$F(1,46) = 4.08$, $p = .049$, $\eta^2 = .08$]. Planned comparisons showed that the most interesting condition (no-think with words) showed higher levels of forgetting in the 100% training (14% forgetting) condition compared to forgetting in the 50% training condition (2% forgetting), ($t(46) = 3.72$, $p < .001$). There were no other differences in the other comparisons between 50% group and 100% training conditions (think with word, baseline with word, baseline with pseudo-words).

Substitute thoughts questionnaire. In order to assess the degree of association between targets and substitute words, we asked participants to report the substitutes that they used for each cue when it appeared in red font (no-think condition). A total of 247 substitutes were used (5.14 words per participant, for 6 no-think cues) when the cue was a word. The total number of substitutes reported when the cue was a non-word was 62 (1.3 words per participant). We trained two independent judges to evaluate the semantic association between substitutes and the corresponding target. The judges were presented with each target and the substitute and asked to rate the semantic association using a five-point scale, ranging from 0, which indicated “absence of association” to 4, which indicated “strong association”. The overall mean ratings of association reported were less than 1 point for both judges (for

the first judge was 0.53 (s.d= .92), for the second judge it was .48 (s.d= .91)). Interjudge agreement was high .929 (it remained high -.845- when the participant who explicitly used substitutes related to the targets was removed). Interjudge agreement was calculated with the interclass correlation index, calculated by a two-way random model (Gallucci & Leone, 2013). The mean association between the substitutes elicited with pseudo-word cues and the original targets was .47 (s.d.= .81) for judge 1 and .41 (s.d.=.80) for judge 2. The mean association between the substitutes elicited with word cues and the original targets was .76 (s.d.= 1.21) for judge 1 and .76 (s.d.= 1.23) for judge 2 (when the only participant who explicitly reported using substitutes related to the targets was removed the means become .39 (s.d.= .66) for judge 1 and .44 (s.d.= .68) for judge 2 for the word cues, and .43 (s.d.= .68) for judge 1 and .41 (s.d.= .65) for judge 2 for the pseudo-word cues (see table 2).

Strategy questionnaire. The results on the strategy questionnaire showed that the participants complied with task instructions. Specifically, to the question "did you successfully manage to avoid thinking about targets"? 27% of the participants answered "at least in 50% of the cases"; 50% answered "at least in 75% of the cases" and 8.3% answered "in the 100% of the cases". To the question "For how many words (or no words) did you manage to avoid thinking of the word associated with?", 29.1% answered "at least in the 50% of the cases"; 47.9% answered "at least in 75% of the cases" and 10.4% answered "in 100% of the cases". To the question "Which kind of strategy did you predominantly use trying to avoid to associate word?", 81.2% of participants said "I tried to associate something else to each word", and 10.4% "I tried to keep my mind clear".

General Discussion

The aim of the present study was twofold. First, it was designed to delineate the conditions under which people can use the thought substitution strategy to limit retrieval of unwanted information. Our hypothesis was that thought substitution relies on accessing associates to the presented cues, and we tested this hypothesis using both words and pseudo-words as cues. In two experiments participants were asked to use diversionary thoughts to stop retrieval of targets in the No-Think condition without specific aids (as in the original study by Hertel and Calcaterra, 2005). We documented that specific thought substitutes provided to participants are not necessary to induce successful forgetting in the TNT task. Forgetting was obtained in both experiments, a result which replicates the pattern observed by Bergström et al. (2009). The present study, however, extended these findings by showing that under certain conditions such general instructions can also become ineffective. When pseudo-words poor in semantic information were used as cues, the thought substitution strategy did no longer lead to forgetting of targets. We suggest that this occurs because when asked to divert their thoughts in order to stop thinking about the to-be-suppressed target items, thought substitutes need to be readily available. Cues lacking semantic information do not facilitate the creation of appropriate substitutes that can be retrieved in lieu of the targets, and this hinders the effectiveness of the strategy. This result sets an important boundary condition for forgetting resulting from thought substitution.

Second, the study elucidated the mechanisms of forgetting caused by thought substitution engaged in the TNT task. We contrasted the blocking hypothesis, according to which forgetting is due to the interference caused by strengthening cue-to-substitute associations, with the inhibition hypothesis, which assigns forgetting to suppression of the memory representation of targets during competitive retrieval of substitutes. Original targets and substitutes compete for retrieval, and inhibition is necessary to facilitate the retrieval of the substitute items. This latter effect is similar to the effects documented in the retrieval

practice paradigm (Anderson & Bell, 2001). These two hypotheses lead to divergent predictions in respect to whether forgetting should be detected in the independent cue test. If inhibitory mechanisms are responsible for forgetting observed in thought substitution, then forgetting should be obtained also when using an independent probe at test. The fact that cue-independent forgetting was documented in the present study provides unique support for the inhibitory hypothesis (cf. Anderson, 2003), indicating that repeated retrievals of substitutes to avoid retrieval of targets lead to suppression of memory representations of these targets, which is detectable independently of cues used to access memory. The results presented here would seem to indicate that forgetting in the TNT paradigm when thought substitution is encouraged occurs by the same process by which forgetting is induced under conditions of competitive retrieval, as documented by an extensive literature on retrieval-induced forgetting (Anderson, 2003; Anderson & Levy, 2007) .

Forgetting obtained with independent cues in the TNT paradigm when thought substitution is encouraged parallels the results of the studies in which participants are asked directly to suppress retrieval in the No-Think trials in the typical Think-NoThink paradigm (e.g. Anderson & Green, 2001). It seems thus that in the TNT task inhibition is involved in forgetting also when a broader spectrum of strategies is used than previously argued. However, our results also set some boundaries to inhibitory mechanisms at play when a thought substitution strategy is adopted, as they show that inhibition occurs only when substitutes are easily available. In both experiments, inhibition was observed only when cues were words, and not when cues were pseudo-words. And in experiment 2 it was also observed that forgetting due to inhibition (i.e. forgetting with independent probes) was significantly higher when the learning criterion for the original cue-target pairs was set at 100% compared to 50%. In other words, inhibition occurred when targets were stronger competitors of substitutes.

Our results are only in partial agreement with those of a previous investigation on this issue (Bergström et al., 2009). Bergstrom et al., found that, although inhibition was involved when direct suppression was encouraged (a below baseline forgetting is obtained also with independent cues), forgetting no longer occurred with independent cues when the thought substitution strategy was used, suggesting that thought substitution leads to blocking rather than inhibition. Our results would seem to be incongruent with these results in respect to the cue-independent nature of forgetting when using a thought substitution strategy. However this discrepancy in results can be explained by the different learning criterion of the competitors (target items) set in the two studies. While Bergström et al. set the learning criterion at 50% correct, we maximized the likelihood of eliciting inhibitory mechanism by increasing the learning criterion of the competitors to 100%. The higher criterion used here should have led to better encoding of all study pairs and could be responsible for more intrusiveness of targets when participants were trying to retrieve the substitutes. Research on inhibition suggests that the amount of observed forgetting under conditions of competitive retrieval is linked to the intrusiveness of competitors (Anderson, Bjork, & Bjork, 1994). The effectiveness of this hypothesis is attested by the results of Experiment 2, where we directly contrasted the two types of manipulations (50% vs 100% of correct recall in the encoding). Indeed, the results showed an increment in forgetting in the 100% correct recall condition compared to the 50% correct recall condition. It is thus possible that methodological differences can favour either the blocking mechanism, as in Bergström et al., or the inhibitory mechanism, as in our study, leading to discrepant results which can be easily accommodated by a dual-factor theory.

On the other hand, our results support data recently reported by Benoit and Anderson (2012) showing forgetting with independent probes and thought substitution strategy, despite the fact that they used a threshold training of 50%. Their interpretation is that the thought

substitution strategy is effective in a TNT procedure if substitutes do not share any semantic relation with the targets. In order to make our results comparable with the outcome obtained by Benoit and Anderson, we introduced the same post-experimental check as in their experiment. This check consisted in assessing which diversionary thoughts were used by participants in the No-think phase, and assess the degree of semantic relation between the diversionary thoughts and the targets. Because our pairs were created ensuring that cues and targets did not share any semantic relation (to make them comparable with pseudo-word cues), we expected that in our experiment the diversionary thoughts produced by participants in the presence of the cues would not be related to their respective targets. This hypothesis was supported by the data, where just one participant reported using associates related with target and no semantic association was observed between substitution thoughts and targets.

In general, results of both Experiments 1 and 2 support the interpretation of Benoit and Anderson (2012) by showing that the thought substitution strategy is effective in eliciting inhibition in a TNT procedure. We do also note that the absence of semantic relation between substitutes and targets makes the TNT procedure with thought substitution similar to a retrieval induced procedure. Retrieval induced forgetting in a cue independent test has been interpreted as due to inhibition (Anderson, 2003, Weller, Anderson, Gómez-Ariza, Bajo, 2013). Then, we can assume that a similar process is involved in a TNT procedure when the participants are explicitly trained to use substitute thoughts in order to avoid the previously created cue-target associations.

In general our results suggest that thought substitution is an effective strategy for inducing forgetting in the think/no-think procedure, particularly when cues provide enough information to help generate substitutes. In addition, forgetting when the thought substitution strategy is successfully used seems to be due, at least in part, to inhibition.

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