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Cue-independent forgetting by intentional suppression – Evidence for inhibition as the mechanism of intentional forgetting

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ABSTRACT

People are able to intentionally forget unwanted memories through voluntary suppression, as revealed by the Think/No-think (TNT) paradigm. However, the nature of intentional forgetting is controversial. Findings that forgetting is independent of retrieval cues suggest that inhibitory control underlies intentional forgetting, but this result is also in line with an interference account. To resolve this controversy, we have directly contrasted the cue-independent characteristic of suppression versus interference. A double-cue paradigm was used, in which two different cues were associated with the same target during initial memory formation. Only one cue-target association received further interference/suppression training. In the test phase, when both cues were used to retrieve the target, we found that interference caused memory impairment that was restricted to the trained cue-target association, while suppression induced forgetting that generalized to the independent cue-target association. Therefore, the effect of suppression differs from that of interference. The cue-independent forgetting by voluntary suppression indicates that the target memory itself is inhibited, providing evidence that the underlying mechanism of suppression-induced forgetting is inhibitory control.

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1. Introduction

Memory can be established and lost dynamically in one's lifetime. While a particular memory is often intentionally established, how this memory can be intentionally forgotten remains an open question. In order to address this question, Anderson and Green (2001) developed a Think/No-think (TNT) paradigm and found that not thinking about a memory impaired its later retention, thus demonstrating that humans can selectively repress certain memories and forget them voluntarily.

In the TNT paradigm, subjects first study a list of unrelated cue-target word pairs (e.g., ordeal-roach). Then, they perform a Think/No-think task in which, when the cue words from a subset of word pairs are presented, subjects either recall the associated target item or inhibit it from entering their conscious. Finally, memory for all of the target words is tested (e.g., ordeal-r__). Results have shown that recall for the suppressed targets is worse than recall for the baseline targets (on which neither Think nor No-think training has been given), providing the first evidence that intentional suppression is able to cause memory impairment (e.g., Benoit & Anderson, 2012; Bergstrom, de Fockert, & Richardson-Klavehn, 2009; Depue, Curran, & Banich, 2007; Joormann, Hertel, LeMoult, & Gotlib, 2009; Kim & Yi, 2013; Lambert, Good, & Kirk, 2010; Levy & Anderson, 2008; Racsmany, Conway, Keresztes, & Krajcsi, 2012; van Schie, Geraerts, & Anderson, 2013; Waldhauser, Lindgren, & Johansson, 2012).

Anderson and Green (2001) suggested that the underlying mechanism of voluntary suppression was different from that of the traditional interference approach. While interference uses new associations to disrupt the original cue-target association (e.g., in Fig. 1, alternative associations (1) interrupt the original association (2)), suppression requires inhibitory control of the target memory (e.g., in Fig. 1, suppressing target memory (3) directly). Therefore, forgetting by suppression should be independent of retrieval cues, which is not the case for interference. In order to test this hypothesis, they used a critical independent-cue technique, in which new cues that were semantically (not experimentally)

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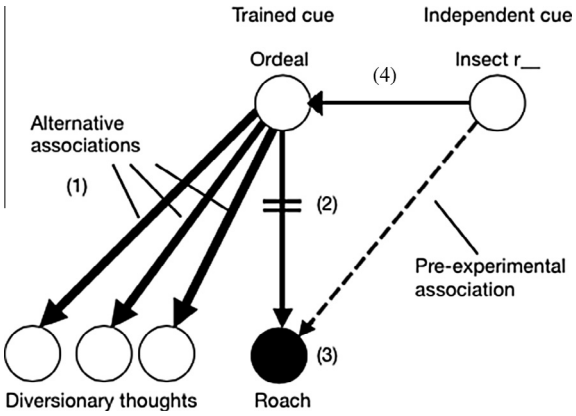

Fig. 1. Possible mechanisms of the TNT paradigm (Anderson & Green, 2001).

associated with the target were used for retrieval in the test phase (e.g., insect-r__) (Anderson & Spellman, 1995). Subsequent research using this independent-cue technique showed that memory was still impaired for voluntarily suppressed targets (Anderson & Green, 2001; Benoit & Anderson, 2012; Bergstrom et al., 2009; Levy & Anderson, 2008). Given that these cues were supposedly independent of any associations formed during the experiment, these findings suggested that the suppression effect was not due to the blocking of the cue-target association and thus seemed to eliminate the role of the interference account in intentional forgetting.

However, recent studies have suggested that under certain circumstances, the cues used in the independent-cue technique may not be as independent as was assumed. Researchers suggested that subjects might think of and covertly retrieve the originally trained cues during the independent-cue test (Camp, Pecher, & Schmidt, 2005; Perfect et al., 2004). For example, Camp, Pecher, Schmidt, and Zeelenberg (2009) used independent cues and found that participants showed an increase in memory recall for items paired with better-memorized trained cues. Because only the trained cues were manipulated in the experiment, independent-cue tests may have been influenced by the accessibility of the trained cues (arrow (4) in Fig. 1), which suggests that the target words may have been retrieved via an independent cue—trained cue—target word pathway. If this is the case, there is no clear difference between the independent-cue test and the trained-cue test, which would suggest that memory impairment found in the TNT paradigm could still be caused by associative interference. This covert cuing explanation has been questioned recently by Weller, Anderson, Gomez-Ariza, and Bajo (2013), who showed that deliberately engaging in covert cuing decreased rather than increased the forgetting effect for independent-cue tests. Although Weller et al.'s (2013) study was not directly testing for intentional forgetting, their results led us to consider the covert-cuing explanation for the TNT paradigm.

In this study we used a double-cue technique to test the roles of inhibition, interference, and covert cuing in intentional forgetting. In this double-cue technique (Table 1), two different cues were paired separately with one common target (e.g., A-T, B-T) for learning, but only one cue-target association received interference (e.g., A_1-*Distractor*) or inhibition training (e.g., A_2-No-think). To test the cue-independent quality of interference- or inhibition-caused forgetting, both cues were used to retrieve the target item (e.g., A-?, B-?). Our hypotheses are as follows: (1) If the No-think instruction is simply creating a form of interference, there should be no difference in the pattern of forgetting between the interference and inhibition conditions. Given that associative interference interrupts the trained cue-target associations, the forgetting effect should be restricted to the trained-cue retrieval. (2) If covert cuing is also in operation, as was claimed by Camp et al. (2009), cue-independent forgetting should also be observed in the interference condition. Thus, if both conditions produce forgetting on both the trained- and the independent-cue test, the data would favor the covert-cuing account and the non-inhibitory theories associated with covert-cuing. (3) However, if forgetting was cue-dependent for interference but cue-independent for No-think training, this would implicate that an additional inhibitory control procedure was happening to the No-think training.

Table 1
Procedure for the interference/inhibition paradigm.

	Learning	Interfere/inhibit training	Test phase	
			Trained cue	independent cue
Interference	A_1-T_1; B_1-T_1	A_1-*Distractor*$_1$	A_1-?	B_1-?
Inhibition	A_2-T_2; B_2-T_2	A_2-No-think	A_2-?	B_2-?
Control	A_3-T_3; B_3-T_3		A_3-?	B_3-?

* A and B represent different cue words, and T represents the common target words; numbers are used here only to signify that words in different conditions are from different subsets.

2. Method

2.1. Participants

Thirty-one subjects (22 female, aged 18–27) were recruited from Peking University, Beijing, China. They were all native Chinese speakers with normal reading and comprehension ability.

2.2. Materials

Forty-eight unrelated Chinese word pairs (e.g., *wisdom-earring*) with relatedness less than 2.5 (as rated on a 7-point Likert scale by 23 subjects who were naïve regarding the aim of the experiment) were used for learning and testing. Each target word was paired with two different cue words (e.g., *wisdom-earring and gardener-earring*), thus two series, 24 word pairs each, in the form of A-T and B-T, were generated. The word pairs were divided into three subsets, which were rotated across subjects through the conditions (interference, inhibition, and control). Relatedness, familiarity (as rated by 100 subjects on a 7-point Likert scale), stroke number, and word frequency (from the Corpus for Modern Chinese Research (Sun, Sun, Huang, Li, & Xing, 1996), which has collected 1.24 million words from a broad range of genres) were balanced across each condition ($p > .05$).

Distractors that were used for interference training consisted of 24 words that were not associated with the cue words. Each distractor was paired with a certain cue word in A-T pairs (e.g., *wisdom-skating*). Accordingly, the 24 distractors were divided into three subsets, and only one subset was used for each subject.

2.3. Procedure

This experiment was an adaptation of the TNT paradigm. It consisted of three phases: associative learning, interference/inhibition training, and testing (Table 1). There were two major differences from the TNT paradigm. First, double-cue/one-target pairs were learned and tested; second, in the second phase, we replaced the Think training with interference training by pairing the trained cue with a distractor.

2.3.1. Associative learning

Forty-eight word pairs (24 A-T and 24 B-T pairs) were presented individually, each for 3 s. After first learning, subjects had to do a self-test with corrective feedback. During the self-test, each cue word was presented first, and subjects were required to recall

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