Psicológica (2006), 27, 57-77.

Inhibitory voluntary control of memory: Effect of stimulus onset asynchrony on reaction time to suppressed memories

Salvador Algarabel*, Juan V. Luciano & José L. Martínez

University of Valencia (Spain)

Anderson & Green (2001) have recently shown that using an adaptation of the go-no go task, participants can voluntarily inhibit the retrieval of specific memories. We present three experiments in which we try to determine the degree of automaticity involved, and the role of the previous prime-target relation on the development of this inhibitory process. In the first two experiments we manipulated stimulus onset asynchrony at test (100 vs. 700), and the type of pre-experimental cue-target relatedness at study (no relation vs. preexisting). Additionally, we carried out an independent probe test in the three experiments. The results show that inhibitory control is only achieved strategically, it is directly linked to the trained stimulus, and it is obtained with episodically and associatively related pairs of stimuli. We discuss these results in terms of clinical and memory research data.

Memory changes comprise the acquisition and forgetting of knowledge or past experiences. In the memory research literature, forgetting has traditionally considered the result of the action of different possible processes as decay, displacement or interference (Crowder, 1976) but not the result of an active suppression mechanism that lowers the activity level of a trace below baseline level (see Anderson, 2003). This theoretical mechanism, long used in attentional studies (Tipper, 1985) is inhibition. By the term inhibition we understand the resulting permanent or temporary reduction in trace strength of a memorized item produced by the active action of an attentional mechanism, which conceivable could be of a

---

* This research was supported by Grant SEJ2004-02541 from The "Dirección General de Investigación Científica y Técnica (Spanish Ministry of Education and Technology) awarded to Dr. Salvador Algarabel. The second author was also the recipient of a pre-doctoral studentship from the Spanish Ministry of Education and Technology. Correspondence should be addressed to Salvador Algarabel. Facultad de Psicologia. Universidad de Valencia. Av. Blasco Ibáñez, 21. 46010. Valencia. Spain. E-mail: Salvador.Algarabel@uv.es

voluntary or automatic nature. In practical terms, the requirement for a stimulus to be inhibited (Anderson & Spellman, 1995) is the demonstration of lower levels of responding in situations in which the stimulus is tested independently of specific cues to which the stimulus was previously linked.

Research on inhibitory mechanisms of memory have increased substantially in the past years as a result of several research programs (e.g. Anderson & Spellman, 1995; Bjork, 1989; Radvansky, 1999), which have produced principled outcomes using the directed forgetting and retrieval practice paradigms. In directed forgetting using the list method[1], people are usually given two lists to learn in sequence, and at some point, they are told that the first list is for practice and should be forgotten, and the second is the to-be-remembered list. The procedure has been generalized not only to list of words, but also to situation models (Radvansky, 1999), or stereotypical materials (Macrae, Bodenhausen, Milne, & Ford, 1997). It is claimed that the lower level of recall of the cued to forget material, in comparison with non cued controls, is due to the action of an active inhibitory mechanism that suppresses the accessibility of the cued to forget list. There are a number of variables known to affect this purportedly proposed inhibitory mechanism. Firstly, the second list learning is a necessary condition to observe lower retention of the first. Secondly, directed forgetting is disrupted or abolished when there are increased attentional demands, like counting vowels on words (Macrae et al., 1997), performing a secondary task or carrying out a concurrent memory load associated with second list learning (Conway et al., 2000). Additionally, list integration through the promotion of high interlist associativeness (Conway et al., 2000) also disrupts directed forgetting.

In the retrieval practice paradigm (Anderson & Spellman, 1995), subjects go to a three phase sequence of tasks. First, they study a set of category-exemplars word-pairs. Then, they practice retrieval on some of the exemplars, and finally, they are tested on the practiced and unpracticed exemplars. Retrieval induced forgetting refers to the worse recall of unpracticed exemplars from the practiced categories with respect to the exemplars from the unpracticed categories. The paradigm has produced a solid set of facts; forgetting is extensible to the retrieval of propositional knowledge (Anderson & Bell, 2001); similarity target-competitor reduces and similarity competitor-competitor increases, integration (Anderson & McCulloch, 1999) protects from impairing recall, and the action of retrieval

[1] The alternative item method consists in presenting a forget or remember cue after each presented item, in a random arrangement. The results obtained with this procedure are not usually attributed to inhibition and will not be considered further.

is also necessary to observe the phenomenon (Anderson Bjork & Bjork, 2000).

More recently, Anderson & Green (2001) have shown that forgetting may be placed under voluntary control in a stop retrieval paradigm (Levy & Anderson, 2002). In their experiments, participants were trained to think and respond to a stimulus word (think trials) and not to think nor respond to others (no think trials). After certain amount of training, subjects were tested in a cued recall test with the same and with an independent cue. Though the difference across levels of training was greater with the same cue test, it also showed up in the independent cue test (Anderson & Spellman, 1995), indicating a possible genuine inhibitory effect.

This demonstration of a decrement in performance associated with the no think training has been proposed to provide a model for the Freudian concept of repression. It is obvious that if we define repression (Anderson & Levy, 2002; Erdelyi, 1993; Freud, 1946; Freud, 1955; Kihlstrom, 2002) as an unconscious process, the think-no think procedure would not serve as a good model for it. But the parallelism become important because the conscious attempts to suppress some memories, thoughts or conscious experiences, something more akin to the technical concept of executive inhibitory control, play an important role in psychopathology. Outwardly, the memory and clinical research literatures show key discrepancies regarding this important aspect. In particular, whereas Anderson & Green' experiments seem to show the way for a technique where one can decrease the activation level of certain memories or past experiences, the assumed consequence (e.g. Wegner, 1994) of attempting thought suppression in clinical settings is a rebound of the suppressed thought. The discrepancy between the clinical and experimental literatures could arise from key methodological questions. In particular, almost all experiments in clinical settings use self report as the dependent variable, whereas accuracy or time measurements are the choices in the experimental literature. This, among others could be a key difference to resolve the incompatibility of results.

However, there is one study (Tolin, Abramowitz, Przeworski, & Foa, 2002) as far as we know, that has used a continuous lexical decision task trying to counteract the criticism to the use of self reports measurements. In their second experiment, Tolin et al. (2002) assumed that thought suppression would lead to faster lexical decision times for suppressed than for nonsuppressed words, if a rebound effect instead of suppression is to be expected. They trained their subjects to suppress the thought of a bear while responding "word-nonword" to a series of stimuli continuously presented. The authors concluded that word suppression led to a momentarily and immediate decrease in reaction times to the suppressed word “bear” only in obsessive compulsive patients, but not in anxious and nonanxious controls. The experiment provided evidence interpreted as support to the rebound interpretation of thought suppression given that obsessive patients, instead of reducing the availability of the suppressed thought, behaved like expected according to the theory of ironic control processes (Wegner, 1994). Paradoxically, there have been also some examples in which thought suppression has led to loss of memory even in the very same clinical literature (Wegner, Quillian, & Houston, 1996). In conclusion, though methodologically very different, the possibility of eliminating worries or any distressing thought seems possible from the results of the experiments by Anderson & Green, but it is not generally thought viable in clinical investigation, because the clinical literature generally support the idea that attempting suppression of a thought increases, instead of decreases, its availability.

In the following experiments we intend to investigate further the empirical properties of this inhibitory process brought under voluntary control in the procedure of stop retrieval designed by Anderson & Green. To do so, we have modified the basic think-no think paradigm to accommodate a final lexical decision task. We pretend to extend the results found by Anderson & Green with an explicit memory task such as cued recall, to a more indirect and implicit procedure as it is lexical decision. This procedure is characterized by showing the effect of one stimulus (the prime) upon another (the target), allowing for the action of expectancies or not as a function of the stimulus onset asynchrony between both (Posner & Snyder, 1975). The reason for choosing a lexical decision task is our desire to investigate the automaticity involved in the development of this type of inhibition. The original demonstration by Anderson & Green involved a “voluntary” action by the subject. However, the fact that finally the inhibition was proved to be independent of the original stimulus, may indicate that it may shows up in tasks in which only automatic effects are allowed to surface, like in lexical decision. This is one of the main reasons to try to obtain the effect with lexical decision tasks.

In addition, we will test the results of the stop retrieval training under different prime-target relations. Past experiments by Anderson and colleagues (e. g. Anderson & Spellman, 1995) on retrieval inhibition have shown that the phenomenon is obtainable with stimulus material semantically related. There could be the possibility that the development of inhibition requires preexisting links between concepts. In anticipation of this possibility we run the basic lexical decision design with weakly related materials (episodic learning: Experiment 1), and with concepts previously related (associatively related: Experiment 2). We also test the target in an independent probe situation to check in which way the results are dependent on prime processing. According to the original formulation by Anderson (Anderson & Spellman, 1995), the inhibitory character of the effect can only be assumed when the target is tested with a cue different to the one used for inhibitory training. As the first two experiments failed to show an inhibitory effect in this independent test we run a third experiment simplifying the procedure, and testing exclusively inhibition with an independent test.

EXPERIMENT 1

Think-No think of episodically related words

This experiment adapts the procedure used by Anderson & Green (2001) with the aim of measuring lexical decision time and not cued recall. As in Anderson & Green (2001) the participants went to a three stage procedure: study, training and lexical decision. We tried to shorten the study and training phases, and at the same time equate for some of the confounding variables known to affect decision times. To equate for familiarity, participants studied word-word and word-pseudoword pairs. As we were not very interested in the effect of "thinking", we assigned the word-pseudoword pairs to the think condition, and the remaining word-word to the no think training. This arrangement did allow us to shorten the study time, and make sure that people accessed the meaning of target words at decision time. Additionally, we selected a single training level (16 trials) for the think or no think training to be compared to the condition in which the stimulus pairs were studied but not trained. Inhibition in this case is the decrease in performance below baseline in the direct and independent tests. This design also kept the duration of the experiment at a reasonable level while equating for familiarity of words and pseudowords. Additionally we manipulated the stimulus onset asynchrony at test (100 and 700 milliseconds). We expect that if no think training gives place to a lower availability of the target word, its lexical decision time will be slower than a control condition. Moreover if it is only strategically mediated, the effect will only shows up at 700 milliseconds. Finally, if the effect becomes some sort of intrinsic property of the target word, the lexical decision times will be also slower in the independent test cue condition. Delivery of the direct and independent tests (same target in both cases but different primes) was carried out in two consecutive blocks in the test phase that were counterbalanced across subjects in this and follow-up experiments. The direct and indirect test conditions were defined by the presentation of the studied item during the test phase. For example, if a subject learnt the association between spoon (prime) and house (target) in the training phase, the presentation of spoon-house or wheel-house, would respectively define the direct and the independent test.

METHOD

Participants. The participants were 80 Psychology students recruited from second and third year of the University of Valencia who received course credit in return for their participation. All of them were neurologically normal and were run in groups of 5 to 10 participants.

Materials and apparatus. All stimuli were presented and lexical decision time measured using e-Prime software (Schneider, Eschman, & Zuccolotto, 2002). Two lists of 20 word triplets were created. One of the lists had as target a word (plus two word primes per target: "prime1, prime2, target"), and the second, a pseudoword (an its corresponding two word primes: "prime1, prime2, pseudoword"). For the word target list, we chose two primes (triplet list), one related and the other unrelated. The frequency per two million (Alameda & Cuetos, 1995) for the three words, were 647 (unrelated), 789 (related), and 478 (targets). The association strength between related words was obtained from the Algarabel, Sanmartin, García & Espert (1986) norms and was an average of 40.88%. The list in which the target was a pseudo word was created along similar lines, except for the fact that the target word was converted to a pronounceable pseudo word changing a letter at random and checking that the resulting letter string was not a legal word. The frequency counts for this case were: 391 & 348. Additionally 10 stimulus pairs were selected for the practice section of the lexical decision. They were extracted from the same stimulus pool as the experimental materials.

Procedure. The procedure followed closely the originally used by Anderson & Green (2001) with the necessary modifications to fulfill our purposes, which included running the experiment in group instead of individually and measure key-press reaction time instead of recall. There were three phases in this experiment: paired associated learning, think-no think training, and lexical decision test. In the first phase, the subject studied a list of 20 paired associated words, and then a list of 20 word-pseudowords pairs in sequence. In the second phase, 10 of the studied word-words served in the no-think, and 10 of the word-pseudowords served for the think trials. Finally, in the third phase a lexical decision test was implemented in two blocks, corresponding to the direct and independent tests. Trial types will be explained in detail below, but the direct and indirect blocks consisted of the presentation of intact studied pairs in the first case, and of the same target again but with a different prime, in the latter. During the initial study phase, the stimulus pairs were presented one at a time, screen centered, according to a study-test procedure. After a study cycle, the participant received a sheet of paper with a different random arrangement of the cue words to write the response. The study-test cycles followed until 50% and 90% criterion response was achieved for word-pseudoword and word-word list respectively. Each pair was presented for 5000 ms with 500 millisecond inter-presentation interval. During the second phase, the participants first learned to recognize the cue words which will later serve for the suppression trials. These cue words were the stimulus primes of each studied pair in the appropriate condition. If the subject was able to identify the suppression cues, he would proceed to the think-no-think phase. If not, an additional study trial was given to achieve good recognition. The instructions emphasized the necessity of thinking and then respond with the studied target, or avoid thinking and not respond in the studied target. We made clear that the critical aspect was to think or not think and that in a subsequent phase of the experiment a forthcoming test would check that instructions were followed. Before going into the true think-no-think section, people were giving 12 warm up trials in which they were familiarized with the procedure. None of the studied stimuli served for this purpose. For the training phase, a fixation cross was displayed first for 200 ms. In case of a "think" trial the studied prime (cue word) was presented until the participant responded with the studied pseudoword or a deadline of 4000 ms was reached, where the computer provided the correct feedback in blue for 500 ms. In the "no-think" trials, the cue word was displayed for 4000 ms. If responded, the computer beeped through an earphone, and the trial was terminated. There were 16 think and 16 no think trials of each stimulus for a total of 160 think and 160 no think trials. After the think-no-think phase was completed, we checked that subjects complied with the instructions testing their knowledge of the pseudoword responses to the activated word stimuli. Then, the lexical decision task followed in which 12 initial practice trials were introduced with stimuli not previously presented. Once the subject fully understood the new task, he was told that none of the previous instructions were in force from this moment on, and that the task now was to respond as fast and accurate as possible to the test word which followed the prime. The test was carried out in two counterbalanced blocks, although from the point of view of the participant there was no transition between them. In block 1, there was 80 trials, 40 in which the target was a word, and 40 for pseudowords. For word targets, 10 trials tested the stimuli only studied and not trained, and 10 more, the suppressed targets. Additionally, another 10 trials presented semantically related words, and 10 unrelated pairs. Both types of stimuli were first seen at test time. Therefore, participants decided on 20 stimulus pairs already presented at study, and on 20 new ones. In block 2, all target tests remained the same, but the primes were varied. In case of the target studied in phase one, the prime was semantically related; the suppressed stimuli got a new prime; and the two conditions in which the stimuli were introduced at test, switched to new primes that were unrelated and related respectively. For pseudowords, block 1 consisted of 10 activated words-pseudowords, 10 studied word-pseudowords, and 20 new word-pseudowords. For block 2, all pseudowords were paired with new primes. The assignation of stimuli to conditions was counterbalanced across participants, such as each stimulus pair appeared equally often in each experimental condition. Two stimulus onset asynchronies were used: 100 and 700 milliseconds, as a between subject manipulation.

RESULTS AND DISCUSSION

Paired associates learning was at a level of 0.41 & 0.52 for pseudowords, and at 0.91 & 0.95 for words at the 100 and 700 ms conditions, respectively. No attempt was made to equate words and pseudowords acquisition given that our interest was centered in the no think training. After the think-no think phase, activated pseudowords were reproduced correctly 0.94 of the times in both asynchronies. Errors (4 and 3% respectively) and response times lower than 300 or higher than 1500 milliseconds (1 and 2%, respectively) were excluded from the analysis. The lexical decision data were analyzed by means of three different analysis of variance to check for the existence of a classic priming effect, then the effect of think training by condition (asynchrony x type of test x training), and then the effect of main interest; the “no think” data (asynchrony x type of test x training). Table 1 presents the average decision time according to the previous rationale.

The effects we report were significant at the $\underline{p}<.05$ level unless otherwise noted. The analysis of asynchrony (100 vs. 700 ms) x type of test (direct vs. independent) x relatedness (non related vs. related) showed an effect of asynchrony, $F(1, 77) = 5.18$, Mse=26049.07, with the short SOA leading to slower responses, and an effect of relatedness, $F(1, 77) = 44.55$, Mse=2095.45, with the unrelated condition being slower, as expected. No other effect reached significance.

Table 1. Mean reaction times, separately by type of analysis (priming, "no think", and "think"), type of test (direct and Independent) and condition (unrelated vs. related, and amount of training: 0 versus 16) for experiment 1.

	Priming				Think				No Think			
	Direct		Independent		Direct		Independent		Direct		Independent	
SOA	Unrel	Rel	Unrel	Rel	0	16	0	16	0	16	0	16
100	663	641	662	629	695	716	693	711	633	650	632	622
700	627	589	630	584	628	569	662	668	560	592	569	583

A second analysis on asynchrony (100 vs. 700) x type of test (direct vs. independent) x training (0 vs. 16) for the "non think" phase showed an effect of asynchrony, F (1, 77) =8.78, Mse=30875.94, and training condition, F(1,77)=5,65, Mse=2493.42, indicating that the no training manipulation slowed down the response. More important, the interaction of type of test by training condition was also significant, F(1,77)=5.46, Mse=1742.09, indicating that "no think" training (16 trials per word) led to slower times in the direct (25 ms difference) than in the independent test (3 ms). No other effect reached statistical significance, although the interaction of training condition by asynchrony was marginally significant, F(1,77)=2.82, Mse=2493.42, p=.10.

Regarding the "think" data, the analysis of asynchrony (100 vs. 700) x type of test (direct vs. independent) x training (0 vs. 16) showed significant effects of asynchrony, F (1, 77) =11.70, Mse=34970.45, and type of test, F (1, 77) =14.60, Mse=98501.31. The interactions of asynchrony by type of test, F(1,77)=18,61, Mse=5292.51, asynchrony by think condition, F(1,77)=10.06, Mse=4084.60, type of test by think condition, F(1,77)=9.49, Mse=2005.86, and the higher order interaction of the three variables, F(1,77)=11.30, Mse=2005.86, were also significant. Looking at the higher order interaction, the analysis indicate that "think" training slower down the decision times to pseudo words at 100 ms at both direct and independent tests. However, at 700 ms, decision times to pseudo words were faster after think training, although the difference disappeared in the independent test. We can conclude from the present data that there is evidence that at short asynchronies the increase in familiarity of pseudowords with think training leads to a slow down of responding, and this is overcome at longer asynchronies. However, we were not very interested in this effect but in the "no think" training. We did not find any evidence in favor of the hypothesis that the "no think" training slowed down responding in an independent test. The significant interaction between test type and training indicates that people were slower in the direct (597 vs 621) than in the independent test (600 vs 603).

EXPERIMENT 2

Think-No think of associatively related words

In this second experiment we investigate again the same previous set of questions but in this case using associatively related stimuli. The use of this type of materials should put under heavier stress the stop retrieval mechanism more in line with what happens in real life when we face stimuli very salient by emotional or motivational content (Kihlstrom, 2002). There are some recent experiments (Hertel & Gerstle, 2003) in which normal people with depressive characteristics (dysphoric) showed lower capabilities to suppress than nondysphoric. On the experimental side, inhibitory semantic priming has been observed previously in a variety of situations other than lexical decision, like in the tip of the tongue phenomenon (Brown & McNeill, 1966), in semantic retrieval (Dagenbach, Carr, & Barnhardt, 1990; Johnson & Anderson, 2004), and in a variety of attentional tasks (Fox, 1995; May, Kane, & Hasher, 1995; Neill, Valdes & Terry, 1995; Tipper & Milliken, 1996) using related stimuli. The experiments on retrieval inhibition of semantic material by Johnson & Anderson (2004) gave practice to the participants in the non-dominant meanings of a homograph or to low frequency exemplars of a category, to show inhibition to the dominant and not practiced meaning or to the higher frequency exemplars. A further task in which subjects had to complete fragments associated to the non practiced homograph meaning or exemplars showed inhibition in the category-exemplar task, but not in the homograph experiment.

The following experiment is similar to the first one, except for the fact that the condition of main interest consisted of pair of words of associatively related stimuli that were also presented for study.

METHOD

Participants. The participants were 72 Psychology students recruited from second and third year of the University of Valencia who received course credit in return for their participation. All of them were neurologically normal and were run in groups of 5 to 10 participants per run.

Materials and apparatus. As in the previous experiment, two lists of 20 triplets each were created; one for the case in which the target was a word and a second one for pseudowords. Two 10 word pairs lists were also elaborated. In one of them, the target was a pseudoword, and in the other prime and target were associatively related. For the word target list, we chose two primes for the triplet list, one related and the other unrelated. The frequency per two millions for the three words were 345 (unrelated), 247 (related), and 369 (targets) (Alameda & Cuetos, 1995). The association strength between related words was obtained from the Algarabel el al. (1986) norms and had an average of 30.97%. The list in which the target was a pseudo word was created along similar lines, except for the fact that the target word was converted to a pronounceable pseudo word changing a letter at random and checking that the resulting letter string was not a legal word. The frequency counts for this case were: 186 and 201 for the two word primes. Additionally 10 stimulus pairs were selected for the practice section of the lexical decision from the same stimulus pool as the experimental materials.

Procedure. The design and procedure were similar to Experiment 1, except as indicated. As in the first experiment there were three training phases: learning, think-no think training, and test, in which there was two blocks of trials in a counterbalanced schema. The learning phase was carried out on 30 pairs of word-pseudoword stimulus pairs, and 30 pairs of related pairs. The think-no think phase was identical to the previous experiment except for the fact that the 10 suppressing pairs were semantically related. The direct testing block presented the following trials: 10 word-pseudoword only studied, 10 activated, and 10 unpaired from the original presentation, 10 word-word pairs only studied, 10 suppressed, and 10 unpaired. Therefore, in this block, all stimuli had been seen previously. For the independent block, the 10 only studied pairs and activated pairs for words and pseudoword targets were presented with a new prime, whereas 10 word-pseudoword and 10 related word-word were presented such as they were studied. In total 60 trials per block, continuously presented, and counterbalanced across subjects.

RESULTS AND DISCUSSION

Paired associates learning was at an average level for pseudowords, 0.45 & 0.55; and at very high for related words, 0.93 & 0.96 for the 100 and 700 ms conditions, respectively. No attempt was made to equate words and pseudowords acquisition given that our interest was centered in the word target conditions. After the think-no think phase, activated pseudowords were reproduced correctly 0.90 & 0.92 respectively for both asynchronies. Errors (3 and 4% respectively) and response times lower than 300 or higher than 1500 milliseconds (1% in both cases) were excluded from the analysis. The lexical decision data were analyzed by means of three different analysis of variance to check for the existence of a classic priming effect, then the effect of think training by condition (asynchrony x type of test), and then the effect of main interest; the "no think" data (asynchrony x type of test x relatedness). Table 2 presents the average decision time according to the previous rationale.

Table 2. Mean reaction times, separately by type of analysis (priming, "no think", and "think"), type of test (direct and independent) and condition (unrelated vs. related, and amount of training: 0 versus 16) for experiment 2.

	Priming				Think				No Think			
					Direct		independent		Direct		independent	
SOA	Unrel	Rel	pseudo	pseudD	0	16	0	16	0	16	0	16
100	638	626	662	699	705	703	709	709	629	631	633	665
700	637	538	626	635	618	594	631	626	535	560	599	589

The effects we report were significant at the $\underline{p}<.05$ level unless otherwise noted. The analysis of asynchrony (100 vs. 700 ms) x type of test (direct vs. independent) x relatedness (unrelated vs. related) showed an effect of asynchrony, F (1, 70) =5.82, Mse=12256.49, with the short SOA leading to slower responses, and an effect of relatedness, F (1, 70) =33.24, Mse=68034.03, with the unrelated condition being slower as expected. The interaction was also significant, F (1,70) =20.35, Mse=3342.35, indicating that the relatedness effect was much bigger at 700 ms.

A second analysis on asynchrony (100 vs. 700) x type of test (direct vs. independent) x training (0 vs. 16) for the no think condition showed an effect of asynchrony, F (1, 70) =19.16, Mse=17798.85, and type of test, F (1,70)=18.20, Mse=4235.01. The interaction of type of test by asynchrony was marginally significant, F(1,70)=3.19, Mse=4235.01, indicating that the independent test was much slower than the direct at 700 than 100 milliseconds. Studied but not trained words (0 training condition) were also faster than words submitted to stop retrieval training (16 training condition), F (1, 70) =5.23, Mse= 2004.88. The higher order interaction, F (1, 70) =11.24, Mse=1749.03, was also significant and difficult to interpret because the mean data indicate that there was an independent test effect at 100 milliseconds (633 vs 665) but not direct (629 vs 631), but the reverse was true at 700 milliseconds for the independent (599 vs 589) and direct tests (535 vs 560). This interpretation was confirmed by t tests, t(35)=2,55 for the indirect test at 100 ms and t(35)=2.43 for 700 ms, respectively. No other individual component of the interaction was significant.

Therefore, although in some of the tests the "no think" condition was slower than the control, the difference reversed depending of asynchrony and type of test in an unpredictable manner.

Regarding the "think" data, the analysis of asynchrony (100 vs. 700) x type of test (direct vs. independent) x training (0 vs. 16) showed significant effects of asynchrony, F (1, 70) =24.57, Mse=23389.34, and the type of test was marginally significant, F (1, 70) =3.05, Mse=4199.70. No other effect or interaction reached significance. As said in the introduction, we were not particularly interested in the pseudoword data (think trials). The fact that pseudowords have no meaning may help to understand why there is no particularly clear facilitatory effect on them. However, as in Experiment 1, the significant effect of amount of training, indicates that the familiarization of pseudowords due to the "think" training slowed down responding. In conclusion the present experiment failed again to show a significant inhibitory effect for the independent test at 700 milliseconds.

EXPERIMENT 3

Independent test of episodically related words

In the previous two experiments we obtained only weak evidence of inhibition as measured by independent tests. The procedure we have used is quite lengthy, and the peculiarity of using pseudowords for thinking trials with the added consequence of different acquisition courses. In this experiment, we pursue a simplification of the procedure and the use of word targets for both; thinking and suppressing. The ultimate reason has to do with experimental precision. As in previous experiments, we base our conclusions in the null results of the independent test, we introduce changes aiming to reduce the length of the experimental session and reduce the possibility of overlearning of some of the experimental pairs. In this way, we hope to let inhibition acts easier in case that the previous null results were caused by lack of precision. To avoid overlearning, we are going now to use Rock´s dropout procedure (1957). In the acquisition phase, as soon as a pair of stimuli was learnt, it was removed from the learning list and the subject continued learning the rest of the material. The think-no think phase remains the same but now carried out on word-word pairs. Previous to the final lexical decision test, we introduced a block of trials on the pseudowords for the purpose of familiarization. Without this block, subjects could base their decision on superficial aspects of the presented words and not on their meaning. We think that semantic access is required either to show facilitation or inhibition. Both sections of the lexical decision phase were undifferentiated from the point of view of the subject.

METHOD

Participants. The participants were 34 undergraduate Psychology students, from the University of Valencia who received course credit in return for their participation. The experiment was run in groups of 5 to 10 participants per run.

Materials and apparatus. Except when noted the apparatus, stimuli and design were similar to the previous two experiments. The study list was composed of 30 words triplets in which one of them was the target and the other two primes. One of the primes was used for training, and the other one for the independent test. Two additional lists were elaborated with the purpose of familiarising pseudowords and new words in the previous phase to the final test. Their frequencies per two million were (Alameda & Cuetos, 1995): 163 (independent cue), 268 (direct cue), 217(target). The frequencies for the familiarisation list were 174 (prime for pseudowords), 126 (primes for words) & 158 (target words). In the first phase, participants studied a list of 30 word pairs. Then, part of the studied word pairs served in the think and no-think trials, and finally a lexical decision task was implemented, after a familiarization phase with the part of the pseudowords that were going to be used later. During the study phase, the word pairs were presented one at a time, screen centered, according to a study-test procedure. For study, each pair was presented for 5000 ms and the time between presentations was 500 ms. For the first test, the stimulus word of each pair was presented at random, and the subject had to write the response using the keyboard. The second study phase included only the stimulus-response pairs not correctly responded in the first phase, as in Rock's dropout procedure (1957). The study-test cycles were repeated until 100% correct was achieved or 3 study-test cycles were completed. With this procedure the rate of acquisition was at a minimum of 0.80 but we wanted to make sure that there was no overlearning of the easy pairs. During the second phase, participants first learned to recognize the cue words which will later serve for suppression trials before proceeding to the think-no-think phase. The instructions for this phase emphasized the necessity of thinking and then respond, or avoid thinking and not respond. We made clear that the critical aspect was to think or not think and that in a subsequent phase of the experiment a forthcoming test would check that instructions were followed. For this phase, an interval of 500 ms with the screen in white and then a fixation cross was displayed for 500 ms. In "think" trials the cue words were presented until a response was made or a deadline of 4000 ms was reached, where the computer provided the correct feedback in blue for 500 ms. In "no-think" trials, the cue words was displayed for 4000 ms. If responded, the computer beep through an headphone. After the think-no-think phase was completed, there was a test of the "think" word pairs, in which the stimulus was presented and the subject had to write its response by means of the computer keyboard.

Previous to the final decision test block, there were a series of lexical decisions, with the purpose of introducing and familiarizing the pseudowords that later would be used. Both types of trials were indistinguishable to the subject. For this familiarization block two lists of 30 prime-target words and 30 prime-target pseudowords were presented, and were repeated 3 times. Then the effective lexical decision block began, including the 30 target words used in the study phase, with words suppressed, activated and simply studied. In all cases, these 30 words were presented with new primes in an independent test. Additionally, we gave 10 new word-word words. To balance the 40 word-word trials, we presented 40 words-pseudoword trials, in which 10 of the pseudoword tests were completely new, and the other 30 were already presented in the familiarization phase. A 700 milliseconds asynchrony between prime and target was used. Previous experiments and the published data indicate that inhibition, as measured by independent tests, is more easily demonstrated with non-automatic situations like the episodic recollection tasks used by Anderson himself. Therefore we elected a 700 ms asynchrony to maximize the possibilities of obtaining an effect.

RESULTS AND DISCUSSION

The learning drop-out procedure produced a 100% acquisition level. After the think-no think phase, activated words were reproduced correctly 92% of the trials. Errors (3%) and response times lower than 300 or higher than 1500 milliseconds (1%) were excluded from the analysis. The lexical decision data were analyzed by means of two different analyses of variance; one for the word, and a different one for the pseudoword targets. Table 3 presents the average decision time according to the previous rationale.

Table 3. Mean reaction times, separately by target type (word, pseudoword), and presentation status: new, old (familiarized pseudowords), studied, and suppressed (no think) or activated (think) for experiment 3.

Pseudoword		Word			
Old	New	New	Studied	No Think	Think
678	729	688	672	646	651

New pseudowords were responded more slowly than familiarized pseudowords, F (1, 33) =26.67, Mse=1635.32. There existed also significant differences among new targets, activated, suppressed and just studied targets, F(3,99)=4.62, MSe=2706.24, p<.01 in both cases. Newman-Keuls tests revealed that only the differences between activated and new, and suppressed and new words were significant, in the sense that new words were slower in both cases. The present experiment confirm the results of the previous two, in the sense that there is no evidence that test words develop inhibitory characteristics

GENERAL DISCUSSION

We think that the present experiments establish three solid facts. First, the lack of inhibitory properties associated with the suppressed target, if we understand by such the observation of slower responding to the target test independently of the original stimulus used for training. This conclusion comes from the fact that all independent tests in the three experiments show negative results; that is to say, the trained target was not slower than the control (0 vs. 16). In the second experiment we observed a slower responding at 100 milliseconds not accompanied by a equivalent result in the direct test. The presence of independent "inhibition" in absence of direct "inhibition" weakened the interpretation of the slower responding as the result of a genuine inhibitory process. Secondly, we have observed the development of suppressing properties by the training stimulus (the prime). This conclusion comes from the fact that in the two first experiments, and putting apart the short asynchronies, the direct tests showed that the trained target showed slower times than the controls (16 vs. 0). Thirdly, we have observed the development of suppressing properties of the prime stimulus, only at 700 milliseconds in the first two experiments. In a previous review paper by Anderson and Spellman (1995), three alternative explanations to inhibition were laid out to account for performance decrements. These are the occlusion, resource diffusion, and associative decrement hypothesis. The common denominator of all of them is that the observed decrement depends on the presence of the original training stimulus. This is why is so important to show response decrement independently of the original training stimulus. Therefore, a possible explanation of the current negative results, although unlikely given previous published literature using alternative paradigms, is the negation of the existence of inhibition.

However, the failure to replicate inhibitory effect by independent test criteria does not necessarily mean the negation of the existence of inhibition as an explanatory mechanism. There are three points on this matter. First, the use of the word "replication" should be taken in this context, as meaning "systematic replication". A replication is the exact reproduction of all procedural details of the original experiment. However, a systematic replication is the implementation of the same logic and a quite close similar design to test a common set of problems. This is the framework of the present investigation and for our use of the term "replication".

Second, the data presented by Anderson and Green themselves (2001) show a very small difference between the experimental and control conditions. In the most recent paper (Anderson, Ochsner, Kuhl, Cooper, Robertson, Gabrieli, Glover, & Gabrieli, 2004) that difference was of the order of 5 to 6% in the independent test. There are already quite a few reports showing null effects on a variety of tasks (Bulevich, Roediger III, & Balota, 2003; Conway & Barnier, 2003; Hertel & Gerstle, 2003). From all of these data, the best conclusion that occurs to us is that intentional forgetting as measured with the think-no think paradigm is a fragile phenomenon. Some recent, and still unpublished data (Hertel & Calcaterra, in press), indicates that the strategy of thinking in something else may helps to develop a greater suppression effect. Unfortunately, the authors only carried out a direct and not an independent test. This is an important point because Anderson and Green recommend explicitly encouraging the participants to think in the stimulus and not in something else. However, besides the discussion on the status of the possible interference effect or whether the developed suppression is really inhibitory or of a different nature, it could well be that "thinking in something else" is a key point in the generation of a suppression effect. As a matter of fact, this is a key procedural difference between research in thought suppression in clinical settings and the think-no think procedure. In the first case, participants are told not to think about an idea (white bear, green rabbit, etc.), whose end effect is a rebound in thinking. In the think-no think procedure, the no think training is linked to specific stimuli upon which the subjects try to center their efforts. Once the prime-target relation is established, one can think of the prime as serving the function of what the clinicians call a distracting stimulus for the no think stimulus. Nevertheless, although the rebound effect is not established without doubts, there are experiments (Wegner, Schneider, Carter, & White, 1987, Experiment 2) indicating that when participants are instructed to supplement their avoidance of one thought with a substitute, the rebound phenomenon is not found. This similarity makes congruent the memory and the clinical data. However, there is a question of ecological validity here. Apparently in real life, we perceive problematic or obsessive ideas as an assault on our attentional system without our control and clear external producing stimulus. This is probably the basis of the extended idea that many of these worrisome thoughts are the product of an automatic unconscious processing system. Nevertheless, the failure to recognize an external producing agent can not be equated with the acceptance of its inexistence. From this point of view we believe that the think-no think paradigm is an adequate simplification of a possible mechanism to unleash obsessive thinking. Moreover, the link between suppression attempts and the generation of obsessions is more correlational than causal. Once a thought has become very absorbent and unpleasant, the subject tries to suppress it, but this is only after he begins to realize that the idea is out of control. It may well be that the population vulnerable to obsessive thinking has some deficit in inhibitory capabilities. The fact that some studies show that there exist individuals so called repressors (low in trait anxiety and high in defensiveness) that at the same time show greater inhibitory capabilities (Myers, Brewin, & Power, 1998; for a review see Myers, 2000) may point out at the same direction.

In any case, we would like to conclude saying that the idea that forgetting or, more in general attentional control, is mainly achieved by inhibitory control (Anderson, 2003) seems an oversimplification of the picture. Classically postulated factors associated to new competing memories looks as candidates to play a big role. The demonstration that "thinking in something else" is an important factor in the development of suppression, at least when measured by a direct test (Hertel & Calcaterra, in press) seems a proof of this point.

RESUMEN

Control inhibitorio voluntario del recuerdo: Efecto del SOA en el tiempo de reacción de los recuerdos suprimidos. Anderson & Green (2001) utilizando una adaptación de la tarea go-no go, han demostrado recientemente que los sujetos pueden inhibir voluntariamente la recuperación de determinados recuerdos. Presentamos tres experimentos, en los cuales tratamos de determinar el grado de automaticidad y el rol de la relación previa entre prime y target, en el desarrollo de este proceso inhibitorio. En los primeros dos experimentos, se manipula la asincronía estimular de la prueba final (100 vs. 700), y el tipo de relación pre-experimental entre el prime y el target (relacionado vs. no relacionado). Adicionalmente, realizamos una prueba independiente al final de los tres experimentos. Los resultados muestran que el control inhibitorio sólo es conseguido estratégicamente, está directamente relacionado con los estímulos entrenados y se obtiene con pares de estímulos episódica y asociativamente relacionados. Finalmente, discutimos nuestros resultados en relación con los datos de investigaciones realizadas en el campo clínico y de la memoria.

REFERENCES

Algarabel, S., Sanmartín, J., García, J., & Espert, R. (1986). *Normas de asociación libre para investigación experimental.* [Free Association Norms for experimental research]. Reports of the Experimental Psychology Laboratory. University of Valencia.

Alameda, J. R & Cuetos, F (1995). *Diccionario de frecuencias de las unidades lingüísticas del castellano* [Frequency Dictionary of the linguistic units of Spanish]. Universidad de Oviedo, Departamento de Psicología, Oviedo.

Anderson, M. C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49*, 415-445.

Anderson, M. C. & Bell, T. (2001). Forgetting our facts: The role of inhibitory processes in the loss of propositional knowledge. *Journal of Experimental Psychology, 130*, 544-570.

Anderson, M. C., & Green, C. (2000). Similarity and inhibition in long-term memory: Evidence for a two-factor theory. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26,* 1141-1159.

Anderson, M. C., & Green, C. (2001). Suppressing unwanted memories by executive control. *Nature, 410,* 366-369.

Anderson, M. C., & Levy, B. (2002). Repression can (and should) be studied empirically. *Trends in Cognitive Sciences, 6*, 502-503.

Anderson, M. C., & McCulloch, K. C. (1999). Integration as a general boundary condition on retrieval-induced forgetting. *Journal of Experimental Psychology: Learning, Memory and Cognition, 25,* 608-629.

Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102,* 68-100.

Anderson, M. C., Bork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin & Review, 7,* 522-530.

Anderson, M. C., Ochsner, K. N., Kuhl, B., Cooper, J., Robertson, E., Gabrieli, S. W., Glover, G. H., & Gabrieli, J. D. E. (2004). Neural systems underlying the suppression of unwanted memories. *Science, 303,* 232-235.

Basden, B. H., Basden, D. R., & Morales, E. (2003). The role of retrieval practice in directed forgetting. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 389-397.

Bjork, E. L., & Bjork, R. A. (1996). Continuing influences of to-be-forgotten information. *Consciousness & Cognition, 5*, 176-196.

Bjork, R. A. (1989). Retreival inhibition as an adaptive mechanism in human memory. In H. L. Roediger III & F.I.M. Craik, eds., *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp 309-330). Hillsdale, NJ: Erlbaum.

Brown, R., & McNeill, D. (1966). The tip-of-the-tongue phenomenon. *Journal of Verbal Learning and Verbal Behavior, 5*, 325-337.

Bulevich, J. B., Roediger, III, H. L., & Balota, D. A. (2003). *Can episodic memories be suppressed?*. XX Meeting of the Psychonomic Society, Vancouver, Canada.

Conway, M. A., & Barnier, A. J. (2003). *Shaping the self: on the accessibility of autobiographical memories*. XX Meeting of the Psychonomic Society, Vancouver, Canada.

Conway, M. A., Harries, K., Noyes, J., Racsma´ny, M., & Frankish, C. R. (2000). The disruption and dissolution of directed forgetting: Inhibitory control of memory. *Journal of Memory and Language, 43,* 409-430.

Crowder, R. G. (1976). *Principles of learning and memory*. Hillsdale, NJ: Erlbaum.

Dagenbach, D., Carr, T. H., & Barnhardt, T. M. (1990). Inhibitory semantic priming of lexical decisions fue to failure to retrieve weakly activated codes. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 328-340.

Erdelyi, M. H. (1993). Repression: The mechanism and the defense. In D. M. Wegner & J. W. Pennebaker, eds., *Handbook of mental control* (pp 126-148). Englewood Cliffs, NJ: Prentice Hall.

Fox, E. (1995). Negative priming from ignored distractors in visual selection: Areview. *Psychonomic Bulletin & Review, 2*, 145-173.

Freud, A. (1946). *The ego and the mechanisms of defense*. (C. Baines, Trans.). International University Press. (Original work published in 1936).

Freud, S. (1955). Notes upon a case of obsessional neurosis. In J. Strachey, ed., *The standard edition of the complete psychological works of Sigmund Freud*. Vol 10. London: Hogarth (Original work published in 1909).

Hertel, P. T., & Calcaterra, G. (in press). Intentional forgetting benefits from thougt substitution. *Psychonomic Bulletin & Review*.

Hertel, P. T., & Gerstle, M. (2003). Depressive deficits in forgetting. *Psychological Science, 14,* 573-578.

Johnson, S. K. & Anderson, M. C. (2004). The role of inhibitory control in forgetting semantic knowledge. *Psychological Science, 15,* 448-453.

Kihlstrom, J. F. (2002). No need for repression. *Trends in Cognitive Sciences, 6*, 502.

Levy, B. J., & Anderson, M. C. (2002). Inhibitory processes and the control of memory retrieval. *Trends in Cognitive Sciences, 6*, 299-305.

Macrae, C. N., Bodenhausen, G. V., Milne, A. B., & Ford, R. L. (1997). On the regulation of recollection. The intentional forgetting of stereotypical memories. *Journal of Personality and Social Psychology, 72*, 709-719.

May, C. P, Kane, M. J., Hasher, L. (1995). Determinants of negative priming. *Psychological Bulletin, 118*, 35-54.

Myers, L. B. (2000). Identifying repressors: a methodological issue for health psychology. *Psychology and Health, 15*, 205-214.

Myers, L. B., Brewin, C. R., & Power, M. J. (1998). Repressive coping and the directed forgetting of emotional material. *Journal of Abnormal Psychology, 107,* 141-148.

Neill, W. T., Valdes, L. A., Terry, K. M. (1995). Selective attention and the inhibitory control of cognition. In F. N. Dempster & C. J. Brainerd (Eds.). *New perspective on interference and inhibition in cognition (pp. 207-261).* New York: Academic Press.

Posner, M. I., & Snyder, C. R. R. (1975). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbit & S. W. Dornic, eds., *Attention and Performance V* (pp 669-682). New York: Academic Press.

Radvansky, G. (1999). Memory retrieval and suppression: The inhibition of situation models. *Journal of Experimental Psychology: General, 128*, 563-579.

Rock, I (1957). The role of repetition in associative learning. *American Journal of Psychology, 70,* 186-193.

Schneider, W., Eschman, A. & Zuccolotto, A. (2002*). E-Prime reference guide*. Pittsburg: Psychology Software Tools Inc.

Tipper, S. P. (1985). The negative priming effect. Inhibitory priming and ignored objects. *Quarterly Journal of Experimental Psychology, 37A,* 571-590.

Tipper, S. P., & Milliken, B. (1996). Distinguishing between inhibition and episodic retrieval based accounts of negative priming. In A. F. Kramer, M. Coles, & G. Logan (Eds.). *Converging operations in the study of visual attention* (pp337-364). Washington, DC: American Psychological Association.

Tolin, D. F., Abramowitz, J. S., Przeworski, & Foa, E. B. (2002). Thought suppression in obsessive.compulsive disorder. *Behaviour Research and Therapy, 40,* 1255-1274.

Wegner, D. M. (1994). Ironic processes of mental control. *Psychological Review, 101*, 34-52.

Wegner, D. M., Quillian, F., Houston, C. E. (1996). Memories out of order: Thought suppression and the disturbance of sequence memory. *Journal of Personality and Social Psychology, 71,* 680-691.

Wegner, D. M., Schneider, D. J., Carter, S. R., & White, T. L. (1987). Paradoxical effects of thought suppression. *Journal of Personality and Social Psychology, 53*, 5-13.

(Manuscript received: 27 April 2004; accepted: 12 April 2005)