

If You Negate, You May Forget: Negated Repetitions Impair Memory Compared With Affirmative Repetitions

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One of the most robust laws of memory is that repeated activation improves memory. Our study shows that the nature of repetition matters. Specifically, although both negated repetition and affirmative repetition improve memory compared with no repetition, negated repetition hinders memory compared with affirmative repetition. After showing participants different entities, we asked them about features of these entities, leading to either “yes” or “no” responses. Our findings show that correctly negating an incorrect feature of an entity elicits an active forgetting effect compared with correctly affirming its true features. For example, after seeing someone drink a glass of white wine, answering “no” to “was it red wine?” may lead one to greater memory loss of the individual drinking wine at all compared with answering “yes” to “was it white wine?” We find this negation-induced forgetting effect in 4 experiments that differ in (a) the meaning given for the negation, (b) the type of stimuli (visual or verbal), and (c) the memory measure (recognition or free recall). We discuss possible underlying mechanisms and offer theoretical and applied implications of the negation-induced forgetting effect in relation to other known inhibition effects.

Keywords: negation, memory, inhibition, false memory

Imagine you have just witnessed a robbery. The robber was holding a sharp knife with a *red* handle as he grabbed a bag from a woman and ran away. A police officer who arrives to investigate the scene asks, “Was the knife handle *black*?” You correctly reply, “No.” Our study demonstrates you are less likely at a later point in time to remember the robber held a knife compared to someone who was asked, “Was the knife handle *red*?” and correctly answered, “Yes.” The current findings suggest that correctly negating a feature of an entity (not black) impairs the memory of that entity (knife) compared to affirming the feature (yes red).

Negations are prevalent in communication. Analysis of students’ natural conversations found that negations are slightly more prevalent than words connoting positive emotions, two times more frequent than words connoting negative emotions, and almost three times more prevalent than words denoting causality (Pennebaker, Mehl, & Niederhoffer, 2003). Still, studies have generally viewed the negation process as secondary, demanding cognitive resources and often leading to memory failure (Carpenter & Just, 1975; Clark & Chase, 1972; Deutsch, Gawronski, & Strack, 2006; Gilbert, 1991; Gilbert, Tafarodi, & Malone, 1993; Horn, 1989; Johnson-Laird, & Savary, 1999; Just & Carpenter, 1976; Kaup,

2001; Lea & Mulligan, 2002). In particular, after processing propositions in the form of “not-X,” people tend to lose the “not” marker and remember “X” (Fiedler, Walther, Armbruster, Fay, & Naumann, 1996; Mayo, Schul, & Burnstein, 2004). The current study explores a powerful facet of negation. Rather than treating negations as markers that are prone to being lost, our study investigates the ability of the negation process to inhibit not only the negated detail itself but also the entity of which the detail is a part. Thus, correctly negating that the “knife’s handle was black” can later lead to a complete memory loss of the presence of the knife. This hypothesis suggests that when we negate, we forget.

Post-Event Information

The current study tests how post-event processing that is triggered by answering a question can affect the memory of an object or an event. This phenomenon is related to a large body of research that focuses on the malleability of memory and specifically on how post-event information (PEI) might alter memory (for a review, see Ayers & Reder, 1998). Most of the PEI studies focused on the creation of false memories—a robust phenomenon whereby misleading online or post-event information creates a memory of an event that never took place or of a detail that was never part of the original information (for a review, see Loftus, 2005). Only a few studies have explored whether PEI impairs an existing memory. Based on the scheme used by Wright, Loftus, and Hall (2001), Figure 1 illustrates the different pathways by which PEI can impair the memory of the original information. In all cases, the actual event consists of a couple going out for dinner, entering the restaurant, ordering food, eating, and paying.

Case (a) in the figure depicts substitution. The original vignette includes a guitar playing in the background. By re-presenting most of the original information (enter, order, pay) while altering one

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a	Original PEI	ENTER → ORDER → GUITAR → PAY ENTER → ORDER → PIANO → PAY
b	Original PEI	ENTER → ORDER → → PAY ENTER → ORDER → PIANO → PAY
c	Original PEI	ENTER → ORDER → GUITAR → PAY ENTER → ORDER → → PAY
d	Original PEI	ENTER → ORDER → <u>ACUSTIC</u> GUITAR → PAY WAS THE GUITAR ELECTRIC?

Figure 1. Post-event information (PEI) effects. Adapted from Wright et al., 2001. Case (d) refers to the effect proposed in the current research.

detail (the piano instead of the guitar), memory of the altered detail (guitar) is replaced (by piano). The idea is that the two representations (guitar and piano) compete, resulting either in a winning by one of the representations or in creation of some type of a mix between them. For example, Loftus, Miller, and Burns (1978) showed that for a scene that includes a stop sign, a question that suggests a yield sign ("Did another car pass the red Datsun while it was stopped at the yield sign?") led to confusion between the two signs. More than half of the participants remembered the yield sign rather than the stop sign.

Case (b) consists of PEI that adds details to the original information. Here, the original information does not include an instrument playing (enter, order, and pay), but the PEI adds a piano playing to the original information, thus planting the false memory of a piano in the restaurant (Loftus & Pickrell, 1995).

Case (c) consists of PEI that omits a detail. The PEI repeats all of the original elements but one (entering, ordering, and paying, while omitting the playing of the guitar, which was part of the original information). Participants who were given PEI that omitted a detail were less likely to remember that detail compared to participants that were not offered any PEI (Anderson, Bjork, & Bjork, 1994; Loehr & Marche, 2006; Macrae & MacLeod, 1999; Shaw, Bjork, & Handal, 1995; Williams, Wright, & Freeman, 2002; Wright et al., 2001).

The assumption that the suggestive information, be it explicit or implicit, influences memory availability explains the effects of the PEI in the three cases (Ayers & Reder, 1998; Brainerd & Reyna, 1998). A suggestion of a new detail that was not part of the original information elevates the activation level of this (false) detail from zero, resulting in the creation of false memory. An omission of a detail, however, lowers the detail's activation level, leading to memory failure. Importantly, both the memory creation and the memory loss concern the particular detail.

The current research (Case [d] in Figure 1) suggests a new form of PEI that does not involve addition or omission of information. We investigate whether a question an individual answers with "no" impairs the memory of that entity more than a question one answers with a "yes." Accordingly, we hypothesize that answering that the guitar was not an electric guitar increases the probability that the presence of the guitar will be forgotten. Note that as one answers the question ("Was the guitar electric?"), he or she must consider the entity (the guitar). In general, such consideration is likely to increase the activation of the entity, leading to enhancement of memory following questioning. Our research investigates whether the nature of reactivation matters. Therefore, the predic-

tion about an impairment of memory following a negative answer offers important insight into the way negations operate.

Negation as an Inhibiting Process

Our predictions are based on findings that show slower reactions to negated concepts (Giora, Fein, Aschkenazi, & Alkabets-Zlozover, 2007; Kaup & Zwaan, 2003; MacDonald & Just, 1989; Tettamanti et al., 2008; Vandenberg, Eerland, & Zwaan, 2012). To illustrate, after reading "Almost every weekend, Elizabeth bakes no bread but only cookies for the children," participants were slower in responding to the noun "bread" than after reading "Almost every weekend, Elizabeth bakes some bread but no cookies for the children" (MacDonald & Just, 1989). Kaup and Zwaan (2003) and Vandenberg et al. (2012) demonstrated that when an item is negated (e.g., "no bread"), its perceptual image weakens. For example, in our minds, we might see the bread less vividly when it is negated compared to when it is affirmed. These findings are consistent with the mechanism of inhibition. The general hypothesis the current research investigates is that correctly negating a feature of an entity inhibits the entity itself, increasing the likelihood that it will be forgotten.

We note that this prediction is a two-step jump from past findings regarding the possibility that negation leads to a cognitive inhibition process. First, prior research explored the inhibition effect of negation, using findings about the latency of accessing the negated concept, such as how long one takes to decide if "bread" is a word or a non-word. By contrast, our research utilizes memory indices—analogue to remembering seeing bread. Second, prior research tested the inhibiting effect of negation regarding the negated feature, whereas we test the proposition that negating a feature of the entity impairs the memory of the entity as a whole. This proposition, of course, is reminiscent of other well-known inhibition effects such as negative priming (Kessler & Tipper, 2004; Neill, 1977; Tipper, 1985, 2001; Tipper, Grison, & Kessler, 2003) and retrieval-induced forgetting (Anderson et al., 1994; Anderson & Neely, 1996; Anderson & Spellman, 1995; Ciranni & Shimamura, 1999; C. M. MacLeod, 1989; M. D. MacLeod & Macrae, 2001; Macrae & MacLeod, 1999). However, these effects are mainly about how the activation of one concept inhibits other competing concepts, whereas we suggest the negation of a feature inhibits the entity of which the feature is a part. We discuss the differences between these previously demonstrated inhibition effects and the current effect in the General Discussion.

Negation Can Activate and Inhibit a Representation

The current research suggests that negating a feature may lead to memory loss of the entity of which the feature is a part. Previous studies demonstrated the opposite, namely, that negation creates a memory of an entity that was absent (Fiedler et al., 1996; Loftus, 2005). To clarify the differences between these two seemingly contradicting findings, we turn to Fiedler et al.'s (1996) paradigm, which we describe in some detail because our study uses a variant.

Fiedler et al. (1996) showed participants a short film of the interior of an apartment. Immediately after viewing the film, the participants were asked to indicate whether a series of objects were present in the apartment they observed. Subsequently, the participants completed a 20-min filler task that was followed by a

second memory test. Fiedler et al. were interested in false memory of objects that were not present in the apartment. Specifically, they compared the memory of (a) non-present objects that were correctly identified as not being in the apartment during the first memory questioning with (b) non-present objects that were not mentioned during the first questioning. Fiedler et al. found that although the participants correctly rejected the presence of non-presented objects in the first memory questioning, they failed to do so in the second memory test. For example, correctly negating the presence of an umbrella stand in the apartment during the first questioning led participants to mistakenly indicate the presence of an umbrella stand during the subsequent memory questioning.

Fiedler et al. (1996) proposed that while participants were thinking about an object in the first memory test and correctly negating its presence in the film, they created a transient representation of the object. This transient representation was activated during the second memory test, leading to false memory. Thus, Fiedler et al.'s study illustrates that negating a non-existing entity can lead to false memory.

Now assume that participants see a *yellow* umbrella stand in the apartment. Furthermore, assume that during the first memory questioning, participants are asked whether the umbrella stand was *green*, and they correctly answered "no." How would this negation process influence memory of the presence of an umbrella stand (with no color mentioned)? Note that in Fiedler et al.'s (1996) study, participants negated (correctly) the presence of objects that were absent, suggesting a rather weak negation process that is based on the lack of a representation; in our variant, participants negate (correctly) an attribute of objects that are actually present. In this case, it is plausible to assume a stronger negation process, based on the presence of a representation, possibly strong enough to induce active forgetting effects. Therefore, we hypothesize that in this case, the negation process will inhibit the entity, relative to an affirmation. That is, rethinking about an object while answering "no" (called *negated repetition*, hereafter) will result in a greater memory loss than rethinking about the object while answering "yes" (called *affirmative repetition*). To use the example of the yellow umbrella stand, after correctly answering the question "Was the umbrella stand green?" with "no," one will tend to forget the presence of the umbrella stand more than after correctly answering the question "Was the umbrella stand yellow?" with "yes." To sum, negation of non-present objects can create false memory; negation of an attribute of a present object might lead one to forget it.¹

Experiment 1

The goal of Experiment 1 was to test whether negating a feature of an entity increases the likelihood that the memory of the entity will be lost. We test this prediction relative to a benchmark of affirming the feature. All participants saw the same stimuli and were then asked to affirm or negate different features of the stimuli. We probed the participants' memory for stimuli, which involved an affirmed detail or a negated detail.

Method

Participants. Forty undergraduates participated in the experiment for course credit or payment (the equivalent of \$5).

Materials and procedure. Following Fiedler et al. (1996), we created an 8.15-min video of a virtual tour of an apartment. We instructed the participants to watch it carefully because we would be asking them about the film later. Immediately after viewing the film, the participants took the first memory test. Specifically, they were instructed as follows:

This experiment includes two apartments. You saw one of them. At this stage, you will see a series of sentences. Your task is to decide whether each sentence refers to the apartment that you have seen or to the other apartment. Please press the "yes" key if the sentence refers to the apartment that you have seen or the "no" key if the sentence refers to the other apartment.²

All 16 sentences in the first memory test pertained to objects the participants observed in the apartment. Eight sentences referred to attributes that did not characterize the objects that were seen in the apartment and, thus, required a "no" response. For example, after viewing a blue carpet in the bedroom, the participants were asked to answer "yes" or "no" regarding the statement, "The carpet in the bedroom was yellow." The other eight sentences described the objects faithfully and thus required a "yes" response. The features we used included the size of the object, its color, being open or closed, and full or empty (see Appendix A). We randomly divided the 16 objects into two sets, each of which was associated with a different type of reply. One group of participants received Set 1 with affirmative questions and Set 2 with negative questions. Another group received the opposite pairing. This procedure was performed twice and resulted in two different random splits, and accordingly four between-participants sets. The 16 questions appeared in random order.

After completing the first memory test, participants performed a 20-min unrelated filler task. Subsequently, we administered a second memory test with the following instructions:

Your task is to indicate whether each item appeared in the apartment that you have seen or in the other apartment. Please press the "yes" key if you think that the item appeared in the apartment that you have seen or the "no" key if you think that the item appeared in the other apartment.

The second memory test included questions about the 16 objects from the first memory questionnaire (all of which appeared in the apartment) and 16 new objects that did not appear in the apartment. The order of presentation was completely randomized. Importantly, in the second memory test, the objects were described without any adjectives or characteristics. For example, rather than asking participants about a blue/yellow carpet, we asked them about the presence of a carpet. Accordingly, the answers to all 16 questions involving objects queried in the first memory test should have been "yes," whereas the responses to the questions pertaining

¹ As discussed in Experiment 2, negated repetitions have two components: negation and repetition. The forgetting effect hypothesized here refers to the net impact of negation and is therefore assessed relative to affirmative repetition. The total impact of negation repetitions, which is assessed relative to no repetition, is hypothesized to be an enhancement of memory.

² In line with Fiedler et al. (1996), we used the "two apartments" cover story to ensure a negated answer does not imply the non-existence of the object, but rather only its incongruency with the seen film. We employed this cover story in Experiments 1 and 2 but not in Experiments 3 and 4.

to the 16 new objects should have been “no.” The response keys were counterbalanced between participants. Experiment 1 tests the hypothesis that a correct negation (i.e., answering “no”) in the first memory test hampers the memory of the object compared to a correct affirmative response.

Results and Discussion

We excluded two participants from the analyses: one was color blind (some of the questions referred to color), and the other erred in 50% of the answers in the first memory test.

First memory test. The first memory test included statements that pertained to objects that were present in the apartment. Half of these statements referred to objects with their correct attribute and thus should have elicited a “yes” response. The other half described objects with an incorrect attribute that should have elicited a “no” response. The participants were mostly accurate in their answers, with similar error rates for statements requiring “no” (12.17%) and “yes” responses (17.11%), $t(37) = 1.48, p = .14$.

Second memory test. The question of interest concerns the influence of affirmative versus negative responses in the first memory test on the memory loss of the objects in the second memory test. For each participant, we calculated the proportion of target objects (i.e., objects present in the apartment) the participant reported as not being present in the apartment. We performed this calculation separately for objects the participant correctly answered with a “yes” response and objects correctly answered with a “no” response in the first memory test.³

The analysis revealed that in the second memory test, the participants were significantly more likely to forget the existence of the objects after correctly answering “no” in the first memory test (12.29%) than after correctly replying “yes” (5.51%): paired t test, $t(37) = 2.14, p = .038, \eta_p^2 = .10$ (see Figure 2 and Appendix B for full details). The participants correctly rejected the presence of new objects they did not view in the film ($M = 92.10\%$).

An item-level analysis tests whether the pattern of results generalizes over items. The analysis reveals participants forgot objects significantly more following a negative reply (11.91%) compared to an affirmative reply (5.21%): paired t test, $t(15) = 2.61, p = .02, \eta_p^2 = .31$. Out of the 16 target objects, three were remembered perfectly, 10 were forgotten more following a “no” answer, and three were forgotten more after a “yes” answer.

To sum, a negated repetition in which one correctly negates a feature of the entity impaired memory compared to an affirmative repetition in which one correctly affirms a feature of the entity. The participants were more likely to forget they had viewed an object after they negated a specific feature of it than after they affirmed a specific feature.

Experiment 2

Experiment 1 indicates that a negated repetition hinders memory compared to an affirmative repetition. Experiment 2 examines the negation-induced memory loss in light of two benchmark conditions. The primary benchmark is a *no-repetition* condition in which we eliminated the first memory test. We use this condition to test the total effect of negation repetition, that is, to investigate whether thinking about an object and answering “no” (negated repetition) creates more memory loss than having no opportunity to think

about the object again (i.e., no repetition). The second benchmark is a *two-option* condition. Here, the first memory test includes a two-option choice format (e.g., “the carpet in the bedroom was: blue/yellow”). On the one hand, the two-option condition allows respondents to affirm the correct attribute. On the other hand, it refers explicitly to the alternative attribute. The former makes the two-option condition similar to the affirmation condition, the latter, to the negation condition. The comparison to the memory loss following negation allows us to explore the relative dominance of the two forces.

Method

Participants. One hundred and sixteen undergraduates participated in the experiment for course credit or payment (the equivalent of \$5).

Materials and procedure. Experiment 2 included three conditions that differed only in the first memory test. All participants watched the same movie as in Experiment 1. The first memory test implemented the experimental manipulation. The yes/no condition was an exact replication of Experiment 1. Participants saw statements, half of which were a correct description of an object seen in the apartment (e.g., “The carpet in the bedroom was blue”), and half of which were incorrect (e.g., “The carpet in the bedroom was yellow”). The former statements should have elicited a “yes” response, and the latter, a “no” response. The second condition included two-option statements (e.g., “The carpet in the bedroom was: blue/yellow”). Participants responded by indicating the correct option. The left/right order of the two options was counterbalanced in line with the yes/no statements. The third condition did not include the first memory test, and participants continued directly with the filler task. All participants were given the second memory test after performing a 20-min unrelated filler task.

Results and Discussion

We excluded one participant who erred in 50% of the responses to the first memory test. Additionally, we removed one stimulus from the analysis because it was an outlier in the second memory test. Specifically, 53 out of the 115 participants (46.09%) forgot it, whereas the mean forgetting rate of the other objects was 9.94%. We replaced this stimulus in Experiment 3.

First memory test. The first memory test included questions that pertained to the target objects present in the apartment. The participants were generally accurate in their answers. Overall, the yes/no and the two-option conditions had similar mean error rates, $t(75) = 0.76, p = .44$. Considering errors within condition, in the yes/no condition, we found similar error rates for questions requiring “no” (17.05%) and “yes” responses (16.21%), $t(37) = 0.3, p = .76$. In the two-option condition, we found similar error rates for questions requiring a left-side answer (15.02%) and a right-side answer (14.14%), $t(38) = 0.3, p = .73$.

Second memory test. In the analyses reported below, we examine a series of questions. We start by testing whether the

³ For each participant, we included only responses for objects that were answered correctly in the first memory test, because errors in this test indicate an impaired memory of the object unrelated to the yes/no manipulation.

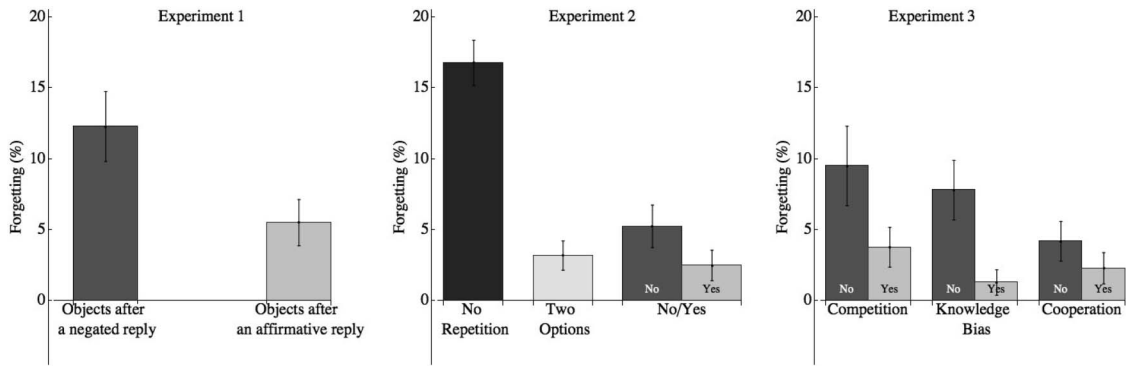


Figure 2. Forgetting objects in the second memory test as a function of the reply in the first memory test following the different conditions in Experiments 1–3. Error bars indicate the standard error of the mean.

memory of participants who had not reactivated the memory of the objects (no repetition condition) is worse than the memory of participants who had to answer a question during the first memory test. Then we investigate how the type of answer affects memory. Does answering “no” impair memory more than answering “yes”? How does having to answer using the two-option response format influence forgetting relative to the “yes” and the “no” responding? As in Experiment 1, the analyses are based on the proportion of the target objects that the participants reported as not being present in the apartment.

The memory loss of the objects that were presented in the film was significantly influenced by the experimental condition, $F(2, 112) = 35.92, p < .01$. This effect is due to the greater memory loss that occurred when participants did not have an opportunity to reactivate their memory ($M = 16.77\%$) compared to having a repetition procedure involving either yes/no responses ($M = 3.96\%$) or two-option responses ($M = 3.19\%$). Simple effect analysis shows that the no-repetition condition differed from each of the other two: the yes/no and no-repetition comparison, $F(1, 112) = 50.36, p < .01$; the two-option and no-repetition comparison, $F(1, 112) = 57.39, p < .01$.⁴

The previous analysis shows repetition matters. In the next analysis, we tested whether the nature of repetition matters as well. Specifically, as in Experiment 1, we compared the memory of the objects following an affirmative reply with the memory following a negative reply. This analysis is based on performance in the yes/no condition. The pattern of findings paralleled Experiment 1. Specifically, the participants were significantly more likely to forget the existence of the objects after correctly answering “no” in the first memory test (5.25%) than after correctly answering “yes” (2.50%): paired t test, $t(37) = 2.04, p < .05, \eta_p^2 = .10$ (see Figure 2). Importantly, the memory loss following a negated reply was significantly lower than the loss found in the “no-repetition” condition, $t(74) = 5.28, p < .01$, supporting the hypothesis that a negated repetition creates two opposite forces. On the one hand, the mere repetition strengthens the memory trace of the entity. On the other hand, compared with an affirmative repetition, a negated repetition hinders memory.

Item-level analysis failed to demonstrate that the nature of repetition matters. That is, the statistical test fails to validate the hypothesis that more forgetting occurs after a negative reply

(5.38%) than after an affirmative reply (2.11%): paired t test, $t(14) = 1.44, p = .16$ (see Appendix B). We believe this failure reflects a floor effect: Eight out of the 15 target objects were associated with perfect memory in the second memory test, obviating memory differences following “no” and “yes” replies in the first memory test. Notwithstanding, of the remaining seven objects that were not remembered perfectly, five were more forgotten after “no” responses.

Our final analysis compares the memory loss following negative and affirmative repetitions to that in the two-option condition. The memory loss following the two-option replies (3.19%) was between the forgetting produced by the negative and the affirmative replies, with no statistically significant difference from either one ($ts < 1$).

Experiment 3

Experiment 3 explores whether the social context in which questions are asked influences the negation-induced forgetting effect. It is well known that linguistic understanding is informed by the intentions of the communicators and, in particular, by the recipients’ interpretation of the communicator’s attempt to have a particular effect on them (e.g., Searle & Vanderveken, 2005). Accordingly, Experiment 3 asks whether the effect of negated repetition differs when the “no” is an answer to a question asked by someone who wants to fail the participant compared to someone who wants to help the participant.

⁴ An important difference exists between the no-repetition condition and the other two conditions. In the yes/no and the two-option conditions, errors in the final memory test were based on items that elicited correct responses in the first memory test. However, the no-repetition condition did not include a first memory test, and therefore item exclusion could not be done. This raises the possibility that the high rate of forgetting in the no-repetition condition is due to the inclusion of items with frail memory trace. Therefore, we repeated the analysis without excluding items based on correct performance in the first memory test. Although the memory loss for the “yes/no” condition (5.08%) and “two options” condition (4.44%) is slightly higher, memory loss in both conditions remains significantly different from the “no-repetition” condition (16.77%), $F(2, 112) = 27.47$.

Method

Participants. Eighty-five undergraduates participated in the experiment for course credit or payment (the equivalent of \$5).

Materials and procedure. Apart from the replacement of six objects (see Appendix C), the film, the first memory test, and the second memory test were the same as in Experiments 1 and 2. One object was replaced because we found that almost half the participants (46%) in Experiment 2 forgot it. Five other objects were replaced because participants in all conditions in Experiment 2 remembered them perfectly, suggesting they were either outstanding (e.g., a specific painting) or too trivial to be included in an apartment (e.g., “lamp”). Replacing these objects gave us the opportunity to generalize the effect to additional details.

To assist the cover story (see below), two unacquainted persons participated in each experimental session. They saw each other briefly as they came into the lab, but they sat in separate rooms during the experiment proper. After watching the identical video of the apartment, all the participants were told, “The current research aims to explore verbal communication among people regarding visual information. While you were looking at the apartment, another participant saw it as well.” They were further told that one of them would have to interrogate the other’s memory. Specifically, the interrogator would write the questions and the other would answer them. We explained the computer would assign them randomly to one of the two roles. However, in actuality, everyone was assigned to answer the memory questions. Participants waited for 3 min (thinking the other participant was writing the questions) before they received the memory questionnaire, which was identical to the first memory test in Experiment 1. They answered the yes/no questions, completed a filler task, and then took the second memory test as in the previous studies.

Unlike the previous experiments, the first memory test was framed as a question–answer game. The three experimental conditions differed in the nature of the game. In the *cooperation* condition, the question–answer game was presented as a cooperative game, as each correct answer gave both participants a point, and the aim was to collect as many points as possible. In the *competition* condition, we presented the question–answer game as a competition between the participants, where “For each correct answer of yours, you will receive a point, but for each mistake, the other participant will get a point. The winner is the one who collects more points.” The third condition, *knowledge-bias*, was presented as in the cooperative condition. However, the participants were told the other participant saw the film in a fast mode, “in a quarter of the time that you had.” We included this condition in order to have a context of uncertainty about the questions but not about the intentions of the source.

Results and Discussion

One participant was colorblind and therefore excluded from the analyses.

First memory test. The participants were generally accurate in their answers. A two-way mixed-model analysis of variance (ANOVA) indicates similar error rates for questions requiring “no” (13.43%) and “yes” (15.22%) responses, $F(1, 83) = 0.93$, $p = .33$. The overall accuracy of answers in the first memory test was invariant to the cover story, $F(1, 83) = 1.21$, $p = .27$. More germane to our analysis, the findings do not provide evidence for

interaction between the two factors, $F(1, 82) = 0.38$, $p = .54$. In particular, simple effect analyses revealed the three conditions had comparable errors for questions requiring affirmative answers, $F(2, 82) = 1.74$, $p = .19$, and negated answers, $F(2, 82) = 0.23$, $p = .63$.

Second memory test. A two-way mixed-model ANOVA was performed on the rates of memory loss. Replicating the previous experiments, there was a significantly greater memory loss following a negated repetition (7.21%) compared to an affirmative one (2.54%), $F(1, 83) = 16.09$, $p < .0001$, $\eta_p^2 = .16$. The cover-story manipulation did not affect memory of the objects, $F(2, 81) = 1.36$, $p = .26$ ($M_{\text{competition}} = 6.77\%$, $M_{\text{cooperation}} = 3.35\%$, $M_{\text{knowledge-bias}} = 4.59\%$). Finally, we found no statistical evidence that the differences in memory loss following “no” and “yes” responses varied as a function of the cover story, $F(2, 81) = 1.62$, $p = .20$ (see Figure 2). Thus participant-level analysis indicates the negation-induced forgetting was robust to the intentions of the person who asked the questions. An item-level analysis reveals that items were significantly more forgotten following a “no” reply (6.89%) than a “yes” reply (2.25%): paired t test, $t(15) = 2.46$, $p = .02$, $\eta_p^2 = .29$ (see Appendix B). Out of the 16 objects, nine were forgotten more following “no,” two were forgotten more after “yes,” and five were either at the same level of memory loss or not forgotten at all.

Experiment 4

Experiment 4 generalizes the negation-induced forgetting effect to recall. The use of a free-recall measure allows us to investigate another potential explanation for the negation effect. According to this explanation, (a) the participants encoded each object together with their initial yes/no responses, and (b) when memory was interrogated during the second test, respondents remembered their responses from their first memory test, which biased their responses in the second memory test. Hence, according to this alternative, answering a question with “no” does not reduce the memory strength of the object. Rather, the negation effect reflects a response-level facilitation of a negative answer in the second memory test.

Experiment 4 explored the negation effect using a free-recall measure, thus eliminating the yes/no responses in the second memory test. In line with our earlier findings, we hypothesized that participants would be less likely to recall a detail whose feature was correctly negated in the first memory test compared to a detail whose feature was affirmed. Moreover, Experiment 4 tests the effect of negation using completely different stimulus information.

Method

Participants. Thirty-one undergraduates participated for course credit or payment (equal to \$5).

Materials and procedure. The initial phase of the study involved the guided imagination of “a typical morning for a student coming to the university.” Fifty-nine sentences describing various details of morning activities appeared consecutively on a computer monitor for 8 s each (see Appendix D). The participants were asked to read each sentence and attempt to imagine the scene as clearly and vividly as possible. Immediately after completing the guided imagination task, the participants received the first

memory test and were presented with 20 sentences, half of which consisted of repetitions of sentences from the imagined scenario (e.g., “You sit in the front of the bus”), and half of which included modified sentences (e.g., “You sit in the rear of the bus”). The participants were asked to press the “yes” and “no” keys to indicate whether each of the 20 sentences was correct or incorrect in the scenarios they imagined. The type of answer (yes/no) was counterbalanced between participants. Subsequently, the participants performed a 20-min filler task, after which they were asked to write down as many details as they could remember from the imagination task. Participants had 12 min to complete this free-recall task.

Results and Discussion

We excluded one participant that appeared to have misunderstood the response keys, leading to 90% errors in the first memory test.

First memory test. The first memory questionnaire included 20 questions all of which referred to details pertaining to the scene they imagined. Half of these questions should have elicited “yes” responses, and the other half should have elicited “no” responses. The participants’ responses to these questions were highly accurate, with similar error rates for questions requiring “no” (8.33%) and “yes” responses (7.33%), $t(29) = 0.96, p = .60$.

Free recall. The free recall of each of the 20 details that were queried in the first questionnaire was coded as “0” if the detail was not mentioned, and “1” if the recall protocol included any mention of the detail, regardless of the specific characteristic of that detail. For example, the guided imagination task presented the following sentence: “The student next to you is reading a printed article.” In the first memory test, participants saw one of two statements (e.g., “The student next to you was reading a book [article]”). We expected the statement that included “book” to yield a “no” response, and the statement that included “article” to yield a “yes” response. In the free-recall coding, any reference to a “student sitting next to me reading” was coded as “1” (to indicate recalling the memory, regardless of the recall of what the student was reading). Two independent judges coded the free-recall protocols and obtained 95% agreement. A third judge resolved disagreements.

For each participant, we calculated the rate of memory failure, that is, the proportion of target items not recalled. We performed this calculation separately for the items the participant correctly affirmed and the items correctly negated in the first questionnaire. The means are depicted in Figure 3 as well as in Appendix B. Failures in recall were more likely when details were negated (25.39%) than when they were affirmed (16.90%): paired t test, $t(29) = 2.46, p < .05, \eta_p^2 = .17$. An item-level analysis reveals that items were significantly more forgotten following a negated reply (25.77%) compared to following an affirmative reply (16.83%): paired t test, $t(19) = 2.64, p = .01, \eta_p^2 = .27$. Out of the 20 items, 14 indicated a greater memory loss following a correct “no” response, four items indicated a greater memory loss after a “yes” response, and two items led to the same level of memory loss.

Interestingly, of all of the items that were answered correctly in the first questionnaire and freely recalled in the second memory questionnaire, less than 1% were false memories (in the example above, “The student was reading a book” rather than an article). In

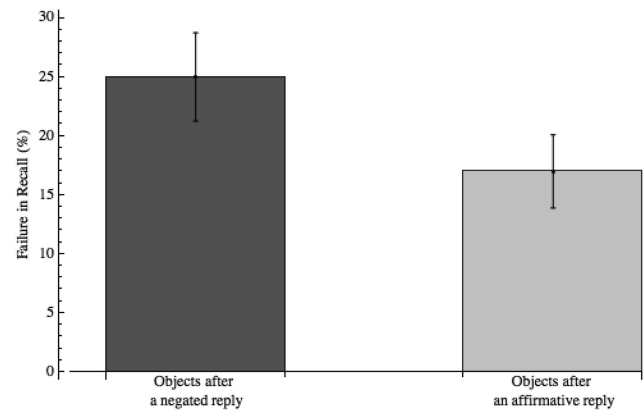


Figure 3. Failure in recall following an affirmative reply versus a negated one in Experiment 4. Error bars indicate the standard error of the mean.

particular, participants did not remember the incorrect portrayals of the detail included in the questions in the first-memory question. This finding is consistent with our earlier suggestion that negation leads to false memory when it refers to non-present objects. By contrast, when the object is present, correctly negating its incorrect feature elicits an active forgetting effect compared to correctly affirming its true features.

General Discussion

Previous research has demonstrated that reactivation of memory improves memory (Bahrick & Hall, 1991; Belmore, 1981; Erdelyi & Becker, 1974; Erdelyi & Kleinbard, 1978; Groninger & Murray, 2004; Kelley & Nairne, 2003; Mulligan, 2001, 2002, 2006; Otani, & Hodge, 1991; Payne, 1987; Popkin & Small, 1979; Roediger & Payne, 1982; Wheeler & Roediger, 1992). The current research proposes a moderating factor: Negated repetitions hinder memory compared to affirmative repetitions. After seeing different entities, our participants were asked about features of these entities, leading to either “yes” or “no” responses. Appendix B provides a summary of the results. In each of the four experiments, we found that correctly negating a feature of an entity led to a greater memory loss of that entity compared to correctly affirming the feature. When we aggregate the results over the four studies (Rosenthal’s, 1978, procedure for adding t s), the effect is highly significant ($Z = 5.19, p < .001$).

The negation-induced forgetting effect was found for two types of episodic information: visual and imagined. We found the effect with three interpretations given to the negation, as being true for the other apartment (Experiments 1 and 2), as being not true for the current scenario (Experiments 3 and 4), and as being part of an attempt to confuse the participant (Experiment 3). Lastly, the negation-induced forgetting effect was indicated by recognition and free-recall measures. Importantly, we find that a negated repetition improves memory compared to no repetition at all. Negated repetitions seem to create two opposite forces. On the one hand, the mere repetition strengthens the memory trace of the entity. On the other hand, compared to an affirmative repetition, a negated repetition impairs memory. But why?

Why do people forget the whole entity rather than remember incorrectly the entity with the wrong attribute? The latter is what happens when the PEI combines with the original representation, as presented in Case (a) in Figure 1. In this case, the memory of the altered detail replaces the memory of the original. Two indications suggest replacement is unlikely to happen in the situations explored in our study. First, when participants could freely report about their memory (Experiment 4), they did not report the false alternative. Second, Case (a) in Figure 1 does not imply memory loss of the whole entity. If anything, it implies its greater activation. To illustrate, participants (Experiment 4) read and imagined that “the bus was 15 minutes late.” Then, they were asked in the first memory test whether “the bus was 10 minutes late.” Our findings in the second memory test indicate the participants tended to forget the bus was late, even though they rethought about the bus as they answered the question by correctly negating it.

To be clear, although we have strong evidence, from four experiments, for the phenomena of the negation-induced forgetting effect, we have no experiment that suggests the underlying cognitive mechanism. Before describing our preferred interpretation of the mechanism, let us discuss two alternative interpretations that minimize the role of negation processes in the effect.

One may argue that the forgetting of the entities after correctly answering “no” in the first memory test is partially due to the memory loss of the objects *prior* to the first memory test rather than to a correct answer (i.e., “no”) based on memory of the objects. Because such initial memory loss leads naturally to failure of memory in the final memory test as well, this interpretation implies the negation-induced forgetting effect is not a function of the negation processing. We believe that the forgetting prior to the first memory test had a minimal role in our experiments. To see why, assume the “no” answer in the first memory test includes two types of responses: (a) correct negations of the wrong feature and (b) failure to remember the entity. This assumption would mean we should have found more correct “no” answers than correct “yes” answers, because the latter are based only on correctly remembered items. In other words, according to this interpretation, we should observe fewer errors for negated responses than for affirmative ones. However, we do not. As the reported findings for each of the four experiments show, not only do we see no significant differences in the error rates for negated and affirmed responses, but in two of the four experiments, there are numerically more errors for “no” answers than for “yes” answers. Accordingly, we believe the contribution of memory failure to the negation-induced forgetting effect is small.

A second alternative explanation for the negation-induced forgetting effect concerns the first memory test’s contamination of the second memory test. Specifically, one could argue that participants encoded each object together with their initial yes/no responses, and when we interrogated memory during the second test, respondents remembered their responses from their first memory test, which biased their responses in the second memory test. Hence, according to this alternative, answering a question with “no” does not reduce the memory strength of the object. Rather, the negation effect reflects a response-level facilitation of a negative answer in the second memory test. We believe this “response bias” is not the case, because Experiment 4 demonstrated the negation effect using a free-recall measure, thus eliminating the yes/no responses in the second memory test.

Below, we offer our speculation for the mechanism that underlies the negation-induced forgetting effect, but we acknowledge that several alternative possible processes remain to be tested. We believe the critical factor in producing the negation-induced forgetting effect has to do with the inhibitory nature of the negation process (Giora et al., 2007; Kaup & Zwaan, 2003; MacDonald & Just, 1989; Tettamanti et al., 2008; Vandenberg et al., 2012). We speculate that while considering a negated-repetition question, one presupposes the negated feature and thereby generates a transient memory representation of the object with the incorrect feature, and then correctly negates it, leading to the inhibition of the object’s representation. Note that the negation-induced forgetting refers to forgetting the presence of the entity, not only the incorrect attribute used in the question. Accordingly, contrary to the impression that research on negation portrays about the fragility of negation, our study emphasizes the inhibition potential of negation to overgeneralize through associative links.

To the best of our knowledge, previous research has not demonstrated this type of inhibition. Inhibition is typically viewed as a process that enables the focusing of attention on one particular pattern of activation by reducing the activation of all other competing patterns (Anderson & Bjork, 1994; Bjork, 1989; Wundt, 1902). Studies have investigated inhibition using several different paradigms. One example is “negative priming,” whereby participants are asked to attend to one stimulus out of two. The stimulus which participants ignored is characterized by a slow response time even when that stimulus becomes the target to be attended to (Kessler & Tipper, 2004; Neill, 1977; Tipper et al., 2003; Tipper, 1985, 2001). Another example is the retrieval-induced forgetting effect whereby in order to activate one memory, the individual inhibits other competing memories (Anderson et al., 1994; Anderson & Neely, 1996; Anderson & Spellman, 1995; Ciranni & Shimamura, 1999; C. M. MacLeod, 1989; M. D. MacLeod & Macrae, 2001; Macrae & MacLeod, 1999). However, the inhibition effect of negation our study investigates includes no competition. One correctly negates a false characteristic of an entity and therefore forgets the entity itself. We did not contrast the inhibited entity (e.g., a carpet) with other entities. The carpet did not compete with any other objects on being present. Still, it was inhibited. The inhibition of the negated feature appears to be spreading to the entity of which it is a part, equivalent to the phenomena of facilitatory priming (e.g., Neely, 1976, 1977) and spreading activation (Freedman & Loftus, 1971; Loftus, 1973; Roediger & McDermott, 1995). MacDonald and Just (1989) tested the possibility of spreading inhibition produced by negation to related concepts. In the example discussed earlier, they investigated the possibility that “no bread” inhibits the concept of “butter.” They failed to find significant slowdown of the related associates of the negated concepts and suggested the equivocal result may be due to the small number of stimuli tested. Our success in showing the spread of inhibition might reflect our use of attribute-entity relationships. Nevertheless, we believe we now have evidence for this spreading-of-inhibition effect of the negation process and that further testing should be done. Is this negation-inhibition effect directional—from features to the entity? Will it spread to other features of the entity? To related entities?

The inhibition mechanism has an adaptive value as a vehicle for mental functioning. It enables the individual to focus on one alternative without the interference of other alternatives. However,

what is the adaptive value of negation-induced forgetting? Why forget an entity as a result of correctly negating one of its features? Speculatively, this phenomenon might be a byproduct of the typical negation process. The mental system might equate negation and falsehood. Because veridical perceptions of conception are important, the mental system might attempt to block and inhibit falsehoods. Such a process may prove efficient when negating false information. If, for example, one believes in a false concept, negating different aspects of it repeatedly may trigger spreading inhibition, leading the perceiver to lose the false concept. Thus, inhibiting the entity whose features are negated might be a useful mechanism for dealing with misinformation (Grant, Malaviya, & Sternthal, 2004; Skurnik, Yoon, Park, & Schwarz, 2005). Put differently, forgetting misinformation might be better than remembering what is incorrect.

Lastly, let us note the significance of the negation-induced forgetting to practitioners. Professionals who interrogate others in the service of finding the truth are often worried about creating false memories. Therefore, they are careful to pose questions without including specific details that may not have been present within a scene (Frenda, Nichols, & Loftus, 2011; Loftus, 2003). Our findings offer another warning to interrogators—they should be aware that questioning in a manner that leads to a “no” response may hinder the memory of the correct information. The negation-induced forgetting effect may seem small, but in real-world phenomena, it is likely to be larger than that observed in our experiments, because the experimental paradigm we used might reduce the size of the effect. Specifically, our participants could have inferred their response in the second memory test from their memory of being asked about the objects in the first memory test. That is, a participant may have concluded, “If I was asked about this object before, I have seen it.” However, outside the experimental paradigm, such a conclusion is not valid. Hence, we believe the negation-induced forgetting effect may be robust in real life with potentially significant impact. To illustrate, consider teachers who purposely present wrong statements for their students to negate. Our findings suggest this practice may backfire by hindering the student’s memory regarding the subject in general. Similarly, interrogators who intentionally ask questions with wrong details in order to test eyewitness knowledge may lead witnesses to lose the memory of correct information. Accordingly, people should think before introducing negations in their communication, keeping in mind that when one negates, one might forget.

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Appendix A

Stimuli for Studies 1 and 2

Initial memory test “yes” statements	Initial memory test “no” statements	Object in final recall test
The phone on the wall was a “key” phone.	The phone on the wall was a dial phone.	phone
The coffee mugs hanging in the kitchen were pink.	The coffee mugs hanging in the kitchen were blue.	coffee mugs
The ashtray was full.	The ashtray was empty.	ashtray
The candleholders by the TV were golden.	The candleholders by the TV were silver.	candle holders
The shopping bag by the sink was empty.	The shopping bag by the sink was full.	shopping bag
The ceiling fan in the living room was “on.”	The ceiling fan in the living room was “off.”	ceiling fan
The bedside lamp was turned on.	The bedside lamp was turned off.	bedside lamp
The painting in the corridor was a picture of circles.	The painting in the corridor was a picture of squares.	painting
The window shades in the living room were closed.	The window shades in the living room were open.	window shades
The sculpture in the glass cabinet was red.	The sculpture in the glass cabinet was blue.	sculpture
The carpet in the bedroom was in shades of blue.	The carpet in the bedroom was in shades of yellow.	carpet
The pillows on the sofa were red.	The pillows on the sofa were black.	pillows
The sign on the bathroom door had a painting of a person on it.	The sign on the bathroom door had a painting of a duck on it.	sign on the bathroom door
The flowerpot by the stairs was big.	The flowerpot by the stairs was small.	flowerpot
The dog on the sofa was lying down.	The dog on the sofa was sitting.	dog
The laptop on the coffee table was open.	The laptop on the coffee table was closed.	laptop

Note. This is a free translation from Hebrew.

Appendix B

Forgetting Objects in the Second Memory Test as a Function of the Reply in the First Memory Test

Experiment	N	% memory loss following “yes”	% memory loss following “no”	No–Yes difference	Effect size
Participant-level analyses					
1	38	5.51 [2.21, 8.82]	12.29 [7.28, 17.32]	6.78 [0.38, 13.18]	0.10*
2	38	2.50 [0.03, 4.67]	5.25 [2.20, 8.29]	2.75 [0.002, 5.48]	0.10*
3	84	2.52 [1.12, 3.90]	7.13 [4.56, 9.69]	4.61 [2.33, 6.89]	0.16*
4	30	16.90 [10.55, 23.25]	25.39 [17.72, 33.05]	8.48 [1.44, 15.53]	0.17*
Item-level analyses					
1	16	5.21 [0.07, 9.71]	11.91 [4.09, 19.72]	6.69 [1.23, 12.15]	0.31*
2	15	2.12 [−0.42, 4.65]	5.39 [0.006, 10.71]	3.27 [−0.01, 8.11]	0.13
3	16	2.25 [0.04, 4.10]	6.89 [2.29, 11.48]	4.63 [0.63, 8.63]	0.29*
4	20	16.83 [9.82, 23.85]	25.77 [16.81, 34.72]	8.93 [1.86, 16.01]	0.27*

Note. Values in brackets indicate a 95% confidence interval.

* $p < .05$.

(Appendices continue)

Appendix C
Stimuli for Study 3

Initial memory test “yes” statements	Initial memory test “no” statements	Object in final recall test
The phone on the wall was a “key” phone. The coffee mugs hanging in the kitchen were pink. The ashtray was full. The candle holders by the TV were golden. The shopping bag by the sink was empty. The chicken in the oven was whole. The drawer by the bed was made of wood. The ball by the entrance was a beach ball. The window shades in the living room were closed. The wall clock was analog. The carpet in the bedroom was in shades of blue. The pillows on the sofa were red. The sign on the bathroom door had a painting of a person on it. The flowers in the vase were red. The dog on the sofa was lying down. The hat on the hanger was a “hat with a visor.”	The phone on the wall was a dial phone. The coffee mugs hanging in the kitchen were blue. The ashtray was empty. The candle holders by the TV were silver. The shopping bag by the sink was full. The chicken in the oven was cut. The drawer by the bed was made of brass. The ball by the entrance was a soccer ball. The window shades in the living room were open. The wall clock was digital. The carpet in the bedroom was in shades of yellow. The pillows on the sofa were black. The sign on the bathroom door had a painting of a duck on it. The flowers in the vase were yellow. The dog on the sofa was sitting. The hat on the hanger was a “Tembel hat” (a name for a round brimless hat).	phone coffee mugs ashtray candle holders shopping bag chicken drawer ball window shades wall clock carpet pillows sign on the bathroom door flowers dog hat

Note. This is a free translation from Hebrew.

Appendix D
Stimuli for Study 4

Initial memory test “yes” statements	Initial memory test “no” statements
During the day, you wore a striped shirt. The bus was 15 minutes late. You were sitting in the front of the bus. The student you were sitting next to was reading an article. You returned the library book to the librarian on the entrance floor. While you were waiting for the bus, you heard an ambulance siren. Your friend was sitting in the third row of the classroom. The student you met in the corridor was wearing a buttoned shirt. The class that you were walking toward was located in building number 4. The student in line for the cafeteria ordered a large coffee. You paid at the cafeteria with a 50 Shekel bill. Your friend complained about the comedy that he watched at the cinema. At the entrance to the bookstore, you saw a sale on computer mice. The book at the bookstore was a paperback. You moved from your seat on the bus for an elderly woman. While your friend was talking, you were switching your cell phone to silent mode. The man at the forum was distributing flyers for the Khan Theater. You drank your coffee with two packets of sugar. The professor was wearing a flowery blouse. The cashier at the bookstore seemed indifferent.	During the day, you wore a plaid shirt. The bus was 10 minutes late. You were sitting in the rear of the bus. The student you were sitting next to was reading a book. You returned the library book through the return window. While you were waiting for the bus, you heard a police car siren. Your friend was sitting in the fifth row of the classroom. The student you met in the corridor was wearing a t-shirt. The class that you were walking toward was located in building number 2. The student in line for the cafeteria ordered a small coffee. You paid at the cafeteria with a 20 Shekel bill. Your friend complained about the drama that he watched at the cinema. At the entrance to the bookstore, you saw a sale on computer webcams. The book at the bookstore had a hard cover. You moved from your seat on the bus for an elderly man. While your friend was talking, you were taking a pen out of your bag. The man at the forum was distributing flyers for the Jerusalem theater. You drank your coffee with one packet of sugar. The professor was wearing a flowery dress. The cashier at the bookstore seemed friendly.

Note. This is a free translation from Hebrew.

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