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Negative priming in free recall reconsidered

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Abstract

Negative priming in free recall is the finding of impaired memory performance when previously ignored auditory distracters become targets of encoding and retrieval. This negative priming has been attributed to an after-effect of deploying inhibitory mechanisms that serve to suppress auditory distraction and minimize interference with learning and retrieval of task-relevant information. In six experiments we tested the inhibitory account of the effect of negative priming in free recall against alternative accounts. We found that ignoring auditory distracters is neither sufficient nor necessary to produce the effect of negative priming in free recall. Instead, the effect is more readily accounted for by a build-up of proactive interference occurring whenever two successively presented lists of words are drawn from the same semantic category.

Keywords: Memory, Negative priming, Free recall

Negative priming in free recall reconsidered

Recent investigations of the phenomenon of forgetting have been driven mostly by the development of a novel theoretical framework which places great emphasis on inhibitory control (Anderson, 2003; Anderson & Spellman, 1995; Bjork, 1989). Whereas traditional, interference-based theories consider forgetting to be a by-product of storing new information, the inhibitory framework postulates a specialized mechanism, or a group of mechanisms, that serves the function of 'deactivating' information which is currently irrelevant. This process of inhibiting currently irrelevant information is thought to have lasting consequences, affecting memory for the irrelevant information on subsequent tests. The active and functional perspective on forgetting embedded in the inhibitory framework opens new fields for examining the role of forgetting in cognitive functioning. Differences in the ability to inhibit irrelevant information have been postulated to play important roles in a range of clinical conditions (e.g., Soriano, Jiménez, Román, & Bajo, 2009; Storm & White, 2010) and the trajectory of cognitive development (e.g., Aslan & Bäuml, 2010) as well as contributing to individual differences in many other cognitive and social domains (Redick, Heitz, & Engle, 2007).

Substantial evidence for the involvement of inhibition in forgetting has been observed in the patterns of neural activity (e.g., Anderson et al., 2004; Depue, Curran, & Banich, 2006; Wimber, Alink, Charest, Kriegeskorte, & Anderson, 2015). However, the extent to which cognitive-level concepts and constructs are subject to inhibitory processes (which may, for example, operate across a different time-scale to those observed in neural activity) remains the subject of a scientific debate between proponents of inhibition- and interference-based theories of forgetting (e.g., Raaijmakers & Jakab, 2013; Verde, 2012) with some commentators (e.g., McLeod, 2007) arguing that neural inhibition does not speak to the existence or form of cognitive inhibition. The three tasks used in the majority of studies aimed at investigating memory inhibition have all attracted both inhibitory and non-inhibitory accounts: the retrieval practice paradigm (for inhibitory accounts see Keresztes & Racsmány, 2013; Norman, Newman, & Detre, 2007; Storm & Levy, 2012, for non-inhibitory accounts see Hanczakowski & Mazzoni, 2013; Jonker, Seli, & MacLeod, 2013; Raaijmakers & Jakab, 2012), the list-method directed forgetting paradigm (for inhibitory accounts see Anderson, 2005; Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008, Racsmány & Conway, 2006, for non-inhibitory accounts see Hanczakowski, Pasek, & Zawadzka, 2012; Sahakyan & Kelley, 2002), and the think/no-think paradigm (for inhibitory accounts see Anderson & Green, 2001; del Prete, Hanczakowski, Bajo, & Mazzoni, 2015; Racsmány, Conway, Keresztes, & Krajcsi, 2012, for non-inhibitory accounts see Hertel & Calcaterra, 2005; Tomlinson, Huber, Rieth, & Davelaar, 2009). This impasse with established procedures has led to the adoption of novel methods.

Recently, an attempt at creating a novel paradigm was undertaken by Marsh, Beaman, Hughes, and Jones (2012; see also Marsh, Sörqvist, Hodgetts, Beaman, & Jones, 2015). In their investigations, Marsh et al. used the already established paradigm of semantic auditory distraction (see Beaman, 2004; Marsh, Hughes, & Jones, 2008; Neely & LeCompte, 1999) and the concept of negative priming (Tipper, 1985), a phenomenon thought to reflect operations of inhibitory functions in perceptual attention (see Tipper, 2001, for a review), to examine memory inhibition. In what follows we describe the procedure for investigating negative priming in free recall developed by Marsh et al. and also the results obtained with it, as related to the issue of memory inhibition.

In the semantic auditory distraction paradigm, which served as the basis of the procedure developed by Marsh et al. (2012), participants study lists of visually presented categorized words for subsequent immediate free recall. During study, auditory distracters are played which participants are told to ignore. For some lists these auditory distracters are taken from the same semantic category that serves as the source of study items, giving rise to a related distraction condition. For other lists, auditory distracters are words taken from a semantic category different to the one used as the source of study items, giving rise to an unrelated distraction condition. The basic finding from this paradigm is that free recall performance of visually presented study words is more impaired in the related distraction condition than in the unrelated distraction condition (Marsh et al., 2008; Neely & LeCompte, 1999).

What makes the semantic auditory distraction paradigm interesting from the perspective of inhibitory mechanisms is that this procedure involves an explicit requirement to ignore auditory distracters in order to facilitate encoding and retrieval of visually presented words. Moreover, the demand placed on the cognitive system to ignore auditory distracters is clearly mediated by the semantic relatedness of distracters to to-be-remembered items, as revealed by differences in subsequent memory performance between related and unrelated distraction conditions. This is in line with generic tenets of the cognitive inhibition approach, namely as a process recruited in the service of suppressing irrelevant information to a degree dependent on the degree of competition caused by irrelevant information (Anderson, Bjork, & Bjork, 1994; Keresztes & Racsmány, 2013). From this perspective, it seems reasonable to assume that inhibition may be recruited to suppress irrelevant auditory distracters in the semantic auditory distraction paradigm, and the extent to which inhibition is recruited depends on the cognitive demands posed by distracters, with stronger inhibitory effects for semantically related distracters compared to unrelated distracters.

Marsh et al. (2012) adopted a working assumption that auditory distracters semantically related to to-be-remembered words should become inhibited in the semantic auditory distraction paradigm and used the logic of negative priming to reveal the after-effects of inhibition. Negative priming in perceptual attention studies is a phenomenon by which, in a naming task, presenting a visual distracter together with a to-be-named item on an *n-1* trial leads to slowed naming of the distracter on the *n* trial, when the previous distracter becomes the target itself. Negative priming has often been attributed to the after-effects of inhibiting a distracter on the *n-1* trial (Tipper, 2001; although note that – as in memory – the inhibitory account has been critiqued; e.g., MacLeod, Chiappe, & Fox, 2002; Treisman & DeSchepper, 1996). Adopting the same approach to the semantic distraction paradigm, Marsh et al. formulated a prediction that inhibiting auditory distracters on the *n-1* trial of encoding and retrieval of a single category list should affect performance on the trial *n*, when items previously used as auditory distracters would serve as to-be-remembered words (see also Hughes & Jones, 2003). The procedure developed by Marsh et al. aimed at testing this prediction.

In the basic negative priming in free recall procedure participants study and recall lists of categorized words. Half of the study lists are accompanied by auditory distracters (either semantically related or unrelated to to-be-remembered [TBR] items). The trials on which distracters are played at study are referred to as prime trials. Each prime trial is followed by a probe trial, on which distracters are not played when the study list is presented. There are two types of probe trials. On ignored repetition probe trials, the same words which were used as auditory distracters on the preceding prime trial, are used as TBR items. Ignored repetition probe trials *always* follow prime trials on which auditory distracters were semantically related to TBR items. On control probe trials TBR items are new, not previously presented, words taken from the category which served as a source of auditory distracters on the preceding prime trial. Control probe trials *always* follow prime trials on which auditory distracters were semantically unrelated to TBR items. The main interest lies in memory performance on probe trials. By comparing memory performance on ignored repetition and control probe trials, Marsh et al. (2012) compared performance for items that were used as semantically related auditory distracters on the previous trials with new items, an analogous approach to negative priming in perceptual attention studies.

The main finding from this procedure was that memory performance on ignored repetition probe trials was worse than performance on control probe trials. Thus, if participants needed to ignore semantically related auditory distracters at prime, memory performance for these distracters when they themselves became TBR items at probe suffered compared to memory performance for novel sets of TBR words. This effect, termed negative priming in free recall, was interpreted as reflecting after-effects of inhibition of words used as TBR items on ignored repetition probe trials (and earlier as semantically related auditory distracters). Two subsequent experiments reinforced the conclusion that inhibitory processes were involved in ignoring semantic auditory distracters (Marsh et al., 2012). In Experiment 2, negative priming was observed only when items of high taxonomic frequency were used as semantically related auditory distracters at prime (and as TBR items at probe), whereas a facilitation in memory performance was found for items of low taxonomic frequency. This finding is consistent with the idea that only items of high taxonomic frequency should compete with encoding/retrieval of related TBR words and thus only such words should trigger inhibition (see Anderson et al., 1994; Storm, Bjork, & Bjork, 2007, for related findings from the retrieval practice paradigm, also interpreted in terms of inhibition). In Experiment 3, facilitation (rather than negative priming) also occurred when ignored repetition probe trials followed prime trials with semantically unrelated distracters, again suggesting that distracters only weakly competing with TBR items at prime do not trigger inhibition.

Although these results are suggestive of the involvement of inhibition in producing negative priming in free recall, there are unresolved issues with this interpretation. The details of the procedure outlined in Marsh et al. (2012) leave open the possibility that the negative priming effect in free recall can be explained by mechanisms other than inhibition. This is of importance given the controversy that inhibitory accounts of other memory phenomena (e.g., directed and retrieval-induced forgetting) have attracted. The need to reconsider evidence for inhibition in free recall and to assess possible alternative accounts is also highlighted by an important theoretical problem that the effect of negative priming in free recall seems to pose when considered in terms of inhibition.

The claim for involvement of inhibitory processes in negative priming in free recall is founded on one major premise: the similarity of the memory results to the phenomenon of negative priming in perceptual attention (Tipper, 2001). However, in perceptual attention studies, inhibition is inferred from slowed responding to re-presented distracters that were previously ignored. By contrast, in memory studies, inhibited items are usually not re-presented and they simply become the targets of retrieval. Re-presenting inhibited items has important, and counterintuitive, consequences in the memory inhibition framework, as shown, for example, by Storm, Bjork and Bjork (2008). Their study employed the retrieval practice paradigm in which inhibition is presumed to be caused by retrieval practice of semantically related items (e.g., the word *banana* is impaired by retrieval of the word *apple*). Storm et al. investigated memory for inhibited items after cycles of retrieval of related items and new learning for presumably inhibited items. The results indicated that inhibited items benefited more from new learning opportunities than control items. These results were discussed in terms of a new theory of disuse, a conceptual framework developed by Bjork and Bjork (1992), in which the memory inhibition ideas are rooted. The new theory of disuse predicts that learning for previously inhibited items should be facilitated, not impaired, and thus the results obtained by Storm et al. were deemed fully consistent with the inhibitory account of forgetting. However, the phenomenon of negative priming in free recall in which new learning for presumably inhibited items is impaired, not facilitated, is in obvious conflict with these results and with this theory[1].

The clash of an inhibitory account of negative priming in free recall with current formulations of the memory inhibition framework as applied elsewhere creates a theoretical conundrum. It could be, of course, that the inhibitory mechanism investigated in the procedure of Marsh et al. (2012) is different from the mechanism described for the retrieval practice paradigm. However, findings from the retrieval practice paradigm pertaining to the issue of competitiveness were used as one of the bases for suggesting that an inhibitory mechanism is involved in producing negative priming in free recall, which makes the idea of two separate inhibitory mechanisms less appealing. Another possibility is that inhibition is not responsible for negative priming in free recall and alternative accounts need to be assessed. In light of these theoretical problems, the present set of experiments was designed to test the inhibitory account of negative priming in free recall against other possible mechanisms that could plausibly give rise to the negative priming effect. In the present study we reconsider the role of inhibition and assess two such alternative mechanisms: source confusion and proactive interference. The source confusion hypothesis postulates that on ignored repetition probe trials participants withhold some of the familiar-seeming retrieved items because they are unsure whether these items were presented at the relevant study phase of the probe trial or served as distracters at the (now irrelevant) study phase of the prime trial.

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[1] Another premise of the inhibitory theory which seems inconsistent with the negative priming in free recall is one of release from inhibition (see Bjork & Bjork, 1996). However, the concept of release from inhibition has been recently criticized on both theoretical and empirical grounds (Lehman & Malmberg, 2009) and thus we do not discuss it further.

The proactive interference hypothesis postulates that memory access on ignored repetition probe trials is impaired because these trials are preceded by prime trials utilizing study items from the same semantic category, which is not the case for control probe trials.

Experiment 1

The first experiment was intended to replicate, using a modified procedure suitable for testing alternative accounts, the basic result of impaired memory performance for items that previously served as semantically related auditory distracters. The present experiment thus establishes the procedure subsequently used to test the inhibitory account of negative priming in free recall against other possible accounts of this effect.

Method

Participants. Twenty-seven undergraduates from Cardiff University participated in exchange for course credit.

Materials. Thirty-six semantic categories were chosen from the norms by Yoon et al. (2004) and by van Overschelde, Rawson, and Dunlosky (2004). For each category, 30 words were chosen and divided into two sets of 15 words, one to be used as study words on prime trials and one to be used as auditory distracters on prime trials. Words used as auditory distracters were recorded in a female voice.

Design. The schematic of the design can be found in Figure 1. Participants studied lists of 15 words from a single semantic category for an immediate free recall task. A study-test block for a single list is referred to as a trial. Each participant studied and recalled 48 lists. Twenty-four of these lists were assigned to prime trials (using 24 out of the chosen 36 semantic categories). On prime trials, auditory distracters were played during study. There were two types of prime trials. On semantically related prime trials (12 lists), auditory distracters came from the same category as visually presented to-be-remembered (TBR) words. On semantically unrelated prime trials (12 lists), auditory distracters came from a different, yoked semantic category that was not used as a source of studied items (the remaining 12 semantic categories). The assignment of lists to conditions was counterbalanced between participants.

The remaining 24 lists were assigned to probe trials (no additional categories were needed for probe trials as these trials presented for study items from categories already utilized for preceding prime trials, either a source of study items or a source of auditory distracters). A probe trial always followed a prime trial. Auditory distracters were not played during probe trials. There were two types of probe trials. On ignored repetition probe trials (12 lists), TBR words were the exact same words which were used as auditory distracters on a preceding prime trial. Importantly, ignored repetition probe trials always followed semantically related prime trials. On control probe trials (12 lists), TBR words were words belonging to the same category as auditory distracters on a preceding prime trial but were novel words. Importantly, control probe trials always followed semantically unrelated prime trials.

Altogether, the design of the present experiment closely followed the design of Experiment 1 reported by Marsh et al. (2012). The significant change in the design is that Marsh et al. used a ratio of ignored repetition and control probe trials of 2:1 (with the same ratio of semantically related and unrelated prime trials) whereas an equal number of ignored repetition and control probe trials, as employed here, serves to make the design more transparent and ensures that the estimate of each individual's performance in all conditions is based upon the same number of observations (trials) per condition.

Procedure. The details of our procedure exactly followed the details of procedure developed by Marsh et al. (2012). Participants were instructed that they would be presented with lists of words for a subsequent immediate recall. They were also instructed that auditory distracters would accompany presentation of some of the lists and that they should try to ignore these distracters the best they could.

Forty-eight experimental lists were presented. During study presentation, each TBR word was presented in the middle of a screen for 750 ms, with 750 ms inter-stimulus interval (ISI). On prime trials, single auditory distracters were synchronously with visual presentation of the studied words. Following the last ISI, a visual prompt 'Recall' was presented for one second and then participants were given 30 s to type in as many words from the just presented lists as they could. After recall period was over, participants pressed the spacebar to initiate the presentation of the next list.

Results and discussion

The descriptive statistics for the correct recall data for all experiments can be found in Table 1. A comparison of free recall performance on prime trials revealed a significant difference between semantically related and unrelated prime trials, $t(26) = 3.68$, $SE = .013$, $p = .001$, $d = 0.56$. This difference replicates the common observation of greater memory disruption under semantically related compared to unrelated auditory distracters (e.g., Marsh et al., 2008; Neely & LeCompte, 1999). More importantly, a comparison of memory performance on probe trials revealed a significant difference between ignored repetition and control probe trials, $t(26) = 2.15$, $SE = .012$, $p = .041$, $d = 0.47$. Worse performance for ignored repetition probe trials compared to control probe trials replicates the effect of negative priming in free recall observed by Marsh et al. (2012).[2] It is worth noting, however, that the effect size for negative priming in free recall documented in the present experiment is smaller than the one shown in the original study of Marsh et al. (d = 0.65). Given this difference in the magnitude of the effect, we also performed a Bayesian analysis of our results (using the JASP software, Love et al., 2015) to examine the strength of evidence for negative priming in free recall. The Bayes factor for the comparison of the negative priming pattern against the null hypothesis was B = 2.83, which is less than the value of 3.00 sometimes viewed as necessary for Bayesian evidence to be considered compelling, see Jeffreys (1961). These results replicate the effect of negative priming in free recall but also suggest that it may be less robust than original data presented by Marsh et al. (2012) implies. This in itself is consistent with recent arguments that effect sizes in replication studies may be systematically smaller than in original reports (Jennions & Møller, 2002; Schooler, 2011).

Experiment 2

The original procedure used to investigate negative priming in free recall, as used by Marsh et al. (2012) and in Experiment 1, contains two confounds that will be a subject of investigation in the present study. Experiment 2 deals with the confounding of the presentational status of items in the probe trials. The procedure adopted in Experiment 1 used previously ignored distracters in the ignored repetition trials and novel items in the control

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[2] In the present study we also analyzed the intrusions participants made on probe trials. In general, intrusions were very rare with less than one intrusion per list (M = 0.46, SD = 0.33) and not different between conditions (p = .10). They also belonged almost invariably to to-be-remembered category which meant that they were predominantly prior-list intrusions for the ignored repetition condition but extra-list intrusions for the control condition. Given the minimal number of intrusions observed here and in all subsequent experiments we do not report the intrusion data for subsequent experiments.

probe trials. Of interest is thus whether negative priming in free recall would be present if this confounding was to be eliminated.

One reason why negative priming in free recall may be eliminated when the confounding of a condition and presentational status is removed concerns the possible roles of source confusions and response withholding in this paradigm. The presentation of items from the ignored repetition probe trials in two different contexts – the distraction context in a prime trial and the learning context in a probe trial – may create a fertile ground for source confusions (which are known to occur anyway within semantic auditory distraction, Beaman, 2004). If an item is retrieved on the ignored repetition probe trial, its recollection may well be accompanied by the awareness that this item was presented as an auditory distracter on a preceding prime trial (e.g., the voice in which this item was presented). The experimenter knows that recalling that an item was an auditory distracter on a prime trial automatically implies that this item was also presented as a TBR word on the probe trial and thus this item constitutes a correct response in a recall test. However, participants are not privy to the specifics of the design and may assume that items presented on the preceding prime trials as distracters will not reappear at probe. In this case, participants may be prone to withhold some of the retrieved items on ignored repetition probe trials, which is not the case for single-context items used on control probe trials.

To remove this confound, Experiment 2 compares performance on the ignored repetition probe trials, which were identical to those in Experiment 1, to performance on modified control probe trials. On modified control probe trials, the items used as auditory distracters on a preceding prime trials were used as TBR words. Modified control probe trials always followed semantically unrelated prime trials, just as control probe trials did in Experiment 1. An illustration of the difference between control (Experiment 1) and modified control trials (Experiment 2) is given in Figure 1.

FIGURE ONE ABOUT HERE

Thus, a comparison on probe trials in Experiment 2 is between items that previously served as semantically related auditory distracters (ignored repetition probe trials) and items that previously served as semantically unrelated auditory distracters (modified control probe trials). Such a comparison holds constant the number of contexts in which the assessed items were presented because all compared items are presented in two different contexts (prime and probe trials).

Method

Participants. Twenty-seven undergraduates from Cardiff University participated in exchange for course credit.

Materials, Procedure, and Design. All details of materials and procedure were the same as in Experiment 1. The only difference in the design compared to Experiment 1 was that on (modified) control probe trials in the present experiment items used as auditory distracters in a preceding semantically unrelated prime trial were used as TBR items.

Results and discussion

The descriptive statistics for correct recall can be found in Table 1. A comparison of free recall performance on prime trials revealed a significant difference between semantically related and unrelated prime trials, $t(26) = 3.96$, $SE = .009$, $p < .001$, $d = 0.65$. This difference once again replicates the observation of greater memory disruption under semantically related compared to unrelated auditory distracters. More importantly, a comparison of memory performance on probe trials revealed a significant difference between ignored repetition and modified control probe trials, $t(26) = 3.78$, $SE = .009$, $p < .001$, $d = 0.58$. The Bayes factor confirmed that evidence favoring the hypothesis of negative priming in free recall over the null hypothesis was very strong, B = 80.86.

In the present experiment, TBR items used for both ignored repetition and modified control probe trials were presented in the context of two different lists, so the effect of negative priming in free recall rules out source confusion as a potential mechanism of this effect and indicates that the confounding of a condition and presentational status in the original study of Marsh et al. (2012) and in the present Experiment 1 was not responsible for the documented effect. However, it is also the case that the observed effect was larger here than in Experiment 1 which, as noted earlier, was smaller than might have been anticipated. To assess this formally, a combined analysis was conducted for probe trials in Experiments 1 and 2[3]. A 2 (condition: ignored repetition vs. control) x 2 (experiment: 1 vs. 2) ANOVA revealed the main effect of condition, $F(1, 52) = 16.00$, $MSE = .002$, $p < .001$, $\eta_p^2 = .24$, consistent with the negative priming effect observed in both experiments, but no main effect of experiment, $F(1, 52) = 1.49$, $MSE = .007$, $p = .23$, $\eta_p^2 = .03$, and, crucially, no interaction, $F < 1$, as might have been expected if the presentational status confound was influencing the appearance of negative priming.

Experiment 3

The results of Experiments 1 and 2 indicate that performance for items used as semantically related distracters at prime trials (ignored repetition probe trials) is impaired compared both to novel items (control probe trials) and items used as semantically unrelated distracters (modified control probe trials). These results are consistent with the inhibitory

[3] We thank Kenneth Malmberg for suggesting this analysis.

account of negative priming in free recall. However, the procedure includes yet another confound which paves way for an alternative account of this effect. Specifically, for ignored repetition probe trials there is a semantic match between TBR items used at prime and probe trials. Because semantically related distracters are used as TBR items on ignored repetition probe trials, these items necessarily come from the same category as TBR items used on a preceding prime trial. By contrast, for both types of control probe trials, TBR items match the category used as a source of distracters on a preceding – semantically unrelated – prime trial and thus there is necessarily a mismatch in categories used as a source of TBR items at prime and probe trials.

The confounding of condition and semantic match leaves the possibility that negative priming in free recall is caused by proactive interference due to a semantic match existing between TBR items at prime and probe in the ignored repetition probe trials (cf. Wickens, 1970), which is clearly evident in Figure 1. To test the possibility of proactive interference, we must first be assured that this phenomenon operates in the present paradigm. This can be easily done be repeating the design of Experiments 1 and 2 but without any auditory distracters at prime so that 'ignored repetition' and control conditions differ only in semantic match between prime and probe trials. If under these conditions we still find the pattern of lower performance in the 'ignored repetition' condition, this will demonstrate semantically-driven proactive interference with the present set of materials. It would also imply that ignoring semantic distracters is not necessary to produce poorer performance in probe trials: the 'negative priming' effect in free recall.

Method

Participants. Twenty-seven undergraduates from Cardiff University participated in exchange for small monetary compensation.

Materials, Procedure, and Design. All details of materials and procedure were the same as in Experiment 2. The only difference in the design compared to Experiment 2 was that no auditory distracters were played on prime trials and thus all trials were completed in silence.

Results and discussion

The descriptive statistics for correct recall can be found in Table 1. A comparison of free recall performance on prime trials revealed no significant difference between 'semantically related' and 'unrelated' prime trials, $t(26) = 0.62$, $SE = .01$, $p = .54$, $d = 0.19$. This lack of difference is hardly surprising as without auditory distracters these prime trials were exactly the same, differentiated only by probe trials that followed them. More importantly, a comparison of memory performance on probe trials revealed a significant difference between 'ignored repetition' and 'modified control' probe trials, $t(26) = 8.18$, $SE = .009$, $p < .001$, $d = 1.43$. This was supported by the Bayes factor, B > 1 000 000, which shows decisive evidence supporting the experimental hypothesis over the null hypothesis. Thus, even after eliminating auditory distracters from the procedure, the pattern of 'negative priming' in free recall was replicated, in this case however as a consequence of the operation of semantically-driven proactive interference.

TABLE ONE ABOUT HERE

Experiments 2 and 3 differed only in the fact that semantically related and unrelated auditory distracters were played on prime trials in Experiment 2 whereas they were eliminated in Experiment 3. We therefore performed an additional analysis combining the results for correct recall from both experiments. Particular interest in this analysis lies in the comparison of ‘ignored repetition’ probe trials between experiments. This comparison holds the semantic match between compared conditions constant, equating them in terms of proactive interference. The inhibition account predicts that performance should be lower in Experiment 2, where probe items served as related distracters at prime, than in Experiment 3, where probe items are new.

For prime trials, a 2 (condition: semantically related vs. semantically unrelated) x 2 (Experiment: 2 vs. 3) ANOVA yielded two significant main effects ($F(1, 52) = 9.67$, $MSE = .001$, $p = .003$, $\eta_p^2 = .16$, for the main effect of condition, and $F(1, 52) = 5.03$, $MSE = .013$, $p = .03$, $\eta_p^2 = .09$, for the main effect of experiment) but also a significant interaction, $F(1, 52) = 4.82$, $MSE = .001$, $p = .033$, $\eta_p^2 = .09$. These results indicate that performance was impaired in Experiment 2 (vs. Experiment 3) when auditory distraction was present and particularly so when distraction was semantically related to TBR items. For probe trials, a 2 (condition: ignored repetition vs. modified control) x 2 (Experiment: 2 vs. 4) yielded a significant main effect of condition, $F(1, 52) = 71.35$, $MSE = .001$, $p < .001$, $\eta_p^2 = .58$, which was qualified by a significant interaction, $F(1, 52) = 9.51$, $MSE = .001$, $p = .003$, $\eta_p^2 = .16$. Despite the significant interaction, pointing to a slightly larger difference between ignored repetition and control conditions in Experiment 3 (without distraction) than in Experiment 2 (with distraction), direct comparison of these two conditions between experiments failed to produce any significant effects, $t(52) = 1.52$, $SE = .02$, $p = .13$, $d = .40$, for the effect of experiment on performance in the ignored repetition conditions, and $t < 1$, for the effect of experiment on performance in the control conditions. Of particular interest is the former comparison, which suggests that the presence (as in Experiment 2) or absence (as in Experiment 3) of related distraction at prime did not have any discernible impact on subsequent memory at probe when semantic match between prime and probe trials was controlled. If anything, the numerical difference favours performance when distraction was present in Experiment 2, which is contrary to the effect predicted by the inhibitory account.

Experiment 4

Although the results of Experiment 3 and the cross-experiment comparison are suggestive, a direct test of both the inhibitory and the proactive interference accounts requires presenting auditory distraction and at the same time equating ignored repetition and control condition in terms of semantic match between TBR items on probe and prime trials. Semantic match within the ignored repetition condition cannot be avoided – related distracters must be presented for study at probe to trigger inhibition, necessarily creating semantic match between prime and probe trials in this condition. What can be done, however, is to create the same match for the control condition. In the control condition, TBR items at probe are accompanied by TBI items from a different category. In the original design of Marsh et al. (2012), novel probe items for control condition come from the same category as TBI items at probe. In Experiment 4, we instead used novel probe items – referred to as *matched control trials* – from the same category as TBR items at probe (see Figure 1). In this way, in both ignored repetition and control conditions there is a semantic match between TBR words on prime and probe trials, equating these conditions in terms of proactive interference.

In Experiment 4 semantic match is preserved for both ignored repetition and matched control trials. Preserving match in both conditions means equating them in terms of proactive interference. If proactive interference, revealed in Experiment 3 with no distraction at prime, is responsible for negative priming in the presence of distraction, negative priming should be absent in Experiment 4. By contrast, the inhibitory account predicts that the negative priming effect should still emerge. This follows from the fact that TBR items used in the new matched control trials are novel words, just as in control probe trials of Experiment 1. If inhibition operates to reduce accessibility of previously ignored auditory distracters, resulting in negative priming, then negative priming should occur whenever inhibited items are compared to a baseline of novel items, independently of whether these novel items are related to a category used as a source of distracters on prime trial (Experiment 1) or a source of TBR items at prime (the present experiment).

A recent study by Marsh et al. (2015, Experiment 2), the results of which we wish to revisit, used the design just described. In this experiment, Marsh et al. found reduced performance for the ignored repetition trials compared to matched control trials, indicating that the negative priming effect persisted even when semantic match was equated between compared conditions (p = .014, 1-tailed test) consistent with the inhibitory account. However, that experiment was primarily intended to test the hypothesis that measures of semantic distraction were associated with working memory capacity, rather than to directly test whether the negative priming effect could be accounted for by proactive interference, and the overall effect of negative priming was relatively small in magnitude (Cohen's d = 0.4) so the issue is worth further examination. We return to these results in the discussion of subsequent experiments.

Method

Participants. Twenty-seven undergraduates from Cardiff University participated in exchange for small monetary compensation.

Materials, Procedure, and Design. All details of materials and procedure were the same as in Experiments 1 and 2. The only difference in the design compared to these experiments was that on (matched) control probe trials in the present experiment items used as TBR items were items taken from semantic category which served as a source of TBR items on a preceding semantically unrelated prime trial.

Results and discussion

The descriptive statistics for correct recall can be found in Table 1. A comparison of free recall performance on prime trials revealed a significant difference between semantically related and unrelated prime trials, $t(26) = 4.11$, $SE = .009$, $p < .001$, $d = 0.63$. This difference once again replicates the observation of greater memory disruption under semantically related compared to unrelated auditory distracters. More importantly, a comparison of memory performance on probe trials revealed no significant difference between ignored repetition and modified control probe trials, $t(26) = 1.72$, $SE = .01$, $p = .10$, $d = 0.36$, and the relatively low (but non-significant) p-value of .10 refers to a result where the means were numerically in the opposite direction to that predicted by the inhibitory account. The Bayes factor analysis showed strong evidence for the null hypothesis, B = .082, over the hypothesis predicting negative priming. These results show that the effect of negative priming is sensitive to the baseline to which performance for ignored repetition probe trials is compared. Even though in the present experiment novel words were used as a baseline (see Figure 1), the fact that these novel words were semantically related to TBR items on the preceding prime trial eliminated the effect of negative priming in free recall.

The results of the present experiment are consistent with a proactive interference account of negative priming in free recall. They implicate semantic congruency between TBR items on prime and probe trials as a main determinant of negative priming. When only ignored repetition probe trials used TBR items from the same category as TBR items on the preceding prime trial, the effect was robustly present (Experiments 1 and 2), but when both ignored repetition and control probe trials use such TBR items, the effect was eliminated. This suggests that semantic congruency of TBR items between prime and probe trials results in proactive interference which impairs learning and/or retrieval on probe trials.

The present results are, however, inconsistent with the inhibitory account of negative priming in free recall and with results obtained by Marsh et al. (2015, Experiment 2). The reasons for this discrepancy in results are unclear. It is possible that the results obtained by Marsh et al. (2015) were the consequence of a statistical false positive, given that those data are conceptually incompatible not only with the results of Experiment 4 but also with the combined analysis of Experiments 2 and 3, which showed no additional effect of ignoring related distracters over and above the effect of proactive interference from previous lists. In Experiment 5 we therefore revisit this combined analysis within a single experimental study to once more assess the viability of negative priming in free recall under conditions of equated semantic match between experimental conditions.

Experiment 5

The combined analysis of Experiments 2 and 3 (the results of which inspired Experiment 4) suggests that the presence or absence of related distraction at prime does not impact upon performance for subsequent probe trial in the ignored repetition condition, which remains impaired. However, this was a cross-experimental comparison. The present experiment sought to assess this issue once more in a single within-participants design. Thus, the present experiment utilized a design comparing the effects of ignoring distracters to the pure effect of proactive interference in the absence of any distraction at prime. There were 4 types of prime-probe pairs of trials, which we refer to as 1) related distraction – semantic match (RD-match), 2) unrelated distraction – semantic mismatch (UD-mismatch), 3) no distraction – semantic match (ND-match), and 4) no distraction-semantic mismatch (ND-mismatch). The first part of the name refers to the type of distraction at prime and the second part refers to a semantic relationship between prime and probe trials. Whenever distraction appeared at prime, the TBI words subsequently served as TBR items at probe.

The main interest again lies in probe trials. A comparison between RD-match and UD-mismatch conditions is a replication of Experiment 2 and is thus similar to the original negative priming paradigm, save for the fact that repeated distracters are used at probe in the UD-mismatch condition as opposed to novel words from the same category (see the introduction to Experiment 2 for the rationale). A comparison between ND-match and ND-mismatch is a pure measure of semantically-driven proactive interference in this design. The comparison between RD-match and ND-match speaks again to whether ignoring distracters at prime leads to an impairment in memory when these items serve as TBR items at probe over and above the negative effect of semantically-driven proactive interference.

Method

Participants. Forty-eight undergraduates from Cardiff University participated in exchange for small monetary compensation.

Materials, Procedure, and Design. The materials and procedure for the present experiment were the same as in previous experiments of this study. We modified the design to accommodate an additional variable: the presence or absence of distraction on prime. Thus, we again used the design of Experiment 2 but for half of the lists at prime trials from the ignored repetition condition and for half of the lists at prime trials from the control condition auditory distraction was eliminated. The lists for which distraction was removed were counterbalanced across participants. In consequence, the RD-match and UD-mismatch conditions that still included distraction at prime were identical to conditions in Experiment 2. The ND-match and ND-mismatch conditions for which distraction at prime was removed were identical to the conditions used in Experiment 3.

Results and discussion

The descriptive statistics for correct recall can be found in Table 1.

Prime trials: The design for prime trials was simpler than the design for probe trials inasmuch as ND-match and ND-mismatch trials were virtually identical at this point of the procedure. We thus collapsed across these two conditions and performed a one-way ANOVA comparing recall performance on prime trials for conditions with no distraction, related distraction and unrelated distraction. The ANOVA revealed a significant effect of distraction, $F(2, 94) = 29.85$, $MSE = .003$, $p < .001$, $\eta_p^2 = .31$. Planned comparisons showed that unrelated distraction impaired performance relative to no distraction, $t(47) = 3.48$, $SE = .01$, $p = .001$, $d = 0.53$, and that related distraction further impaired performance relative to unrelated distraction, $t(47) = 2.76$, $SE = .01$, $p = .008$, $d = 0.40$.

Probe trials: Performance on probe trials was analyzed with a 2 (distraction on prime: present vs. absent) x 2 (semantic relationship between prime probe: match vs. mismatch) ANOVA. Note that, for trials with semantic match, the preceding distraction was related (the RD-match condition), whereas for trials with semantic mismatch, the preceding distraction was unrelated (the UD-mismatch condition). The ANOVA yielded the main effect of semantic relationship, $F(1, 47) = 44.43$, $MSE = .004$, $p < .001$, $\eta_p^2 = .49$, but no effect of distraction on prime, $F(1, 47) = 2.21$, $MSE = .004$, $p = .14$, $\eta_p^2 = .04$, and no interaction, $F < 1$. These results suggest simply that proactive interference operates in this design and its magnitude is unrelated to the presence of distraction at prime.

The specific comparisons conducted in addition to the omnibus ANOVA showed that the results of Experiment 2 replicate as performance was lower in the RD-match vs. UD-mismatch condition, $t(47) = 6.89$, $SE = .01$, $p < .001$, $d = 0.97$, and also that semantically-driven proactive interference disrupted performance even in the absence of distraction at prime, as performance was lower in the ND-match vs. ND mismatch condition, $t(47) = 4.40$, *SE* = .01, $p < .001$, $d = 0.71$ (replicating Experiment 3). Most importantly, a direct comparison of the condition utilizing previously ignored related distracters (RD-match) with the condition preserving semantic match but using novel TBR words at probe (ND-match) showed no significant difference, $t(47) = 1.41$, *SE* = .01, $p = .16$, $d = 0.32$, and if anything the numerical difference was pointing to a slightly better performance in the RD-match condition. The Bayes factor for this crucial comparison showed strong evidence supporting the null hypothesis, B = .066, over the alternate hypothesis of negative priming. These results are clearly inconsistent with the inhibitory account, as they show no impairment due to ignoring distracters beyond impairment arising from semantically-driven proactive interference. As such, these results are consistent with the results of Experiment 4 and the results of the combined analysis of Experiments 2 and 3, but are at odds with results recently reported by Marsh et al. (2015).

Experiment 6

Evidence presented thus far in this series is consistent with the hypothesis that proactive interference is responsible for the pattern of negative priming in free recall. Experiments 3 and 5 clearly demonstrate that proactive interference operates within the original design, as semantic match between prime and probe trials impairs performance even in the absence of any auditory distraction at prime. Experiments 4 and 5, as well as the combined analysis of Experiments 2 and 3, show that adding related distraction at prime (later used as TBR items at probe) does not lead to additional impairment to the one caused by semantically-driven proactive interference.

However, a final strand of evidence that seems to support the inhibitory account of negative priming in free recall has not been addressed. Specifically, Marsh et al. (2012, 2015) included experiments in which it was observed that negative priming in free recall does not emerge if TBR items at prime are of high taxonomic frequency, whereas related distracters and thus also TBR items at probe are of low taxonomic frequency. In both studies, which confounded condition and semantic match in Marsh et al. (2012) but not in Marsh et al. (2015), it was found that such a setup led to positive rather than negative priming of related distracters. The theoretical interpretation of this pattern is based again on the inhibitory framework, which states that only strongly competing information is subjected to inhibition. For example, Anderson et al. (1994) examined the role of taxonomic frequency in the context of the retrieval-practice paradigm and found no retrieval-induced forgetting when to-be-inhibited items were of low taxonomic frequency. According to this argument, when participants study items of high taxonomic frequency and need to ignore auditory items of low taxonomic frequency, these distracters are not sufficiently disruptive to recruit inhibitory processes (but see Jakab & Raaijmakers, 2009; Williams & Zacks, 2001, for contrasting evidence showing an impairment for weakly competing items within the retrieval practice paradigm). Without inhibitory processes, low taxonomic frequency distracters do not suffer any costs when they become TBR items on a subsequent ignored repetition probe trial and may even demonstrate facilitation due to residual activation accrued at prime.

Irrespective of whether inhibition is operative in resisting semantic auditory distraction, the results concerning low frequency distracters in Marsh et al. (2012) are surprising because they show no effect of negative priming despite the confound with semantic match. Since the results of the current Experiments 3 and 5 demonstrate that semantically-driven proactive interference is a significant factor operating in the original design used by Marsh et al. (2012) it is unclear why proactive interference was apparently absent when TBR words at prime were of high taxonomic frequency and TBI words at prime and TBR words at probe were of low taxonomic frequency. We thus present here a further investigation of negative priming of low taxonomic frequency distracters when conditions differ in semantic match. Additionally, the same issue is examined when semantic match is preserved in both conditions as in Marsh et al. (2015).

Experiment 6 employed the same design as for Experiment 5, changing the materials so that TBR words at prime were of high taxonomic frequency, and TBI words at prime and TBR words at probe were of low taxonomic frequency. Again, this design allows us to test several issues. First, a comparison between RD-match and UD-mismatch conditions tests for higher performance in the control compared to the ignored repetition condition – a positive priming effect (as interpreted by Marsh et al., 2012) for low taxonomic frequency distracters. Second, a comparison between ND-match and ND-mismatch is again a pure measure of semantically-driven proactive interference. This comparison will allow for assessing whether varying the taxonomic frequency of items between prime and probe eliminates proactive interference, as Marsh et al. (2012) seems to suggest. Third, the comparison between RD-match and ND-match speaks to whether ignoring distracters at prime leads to an impairment or facilitation in memory– with the later possibility supported by Marsh et al. (2015) – when these items serve as TBR items at probe (RD-match) as compared to the pure effect of semantically-driven proactive interference (ND-match).

Method

Participants. Thirty undergraduates from Cardiff University participated in exchange for small monetary compensation.

Materials, Procedure, and Design. The procedure and design were exactly as in Experiment 5. The materials were sorted into low and high taxonomic frequency words, with the former used as TBI items at prime (in conditions in which distraction was present) and the latter used as TBR items at prime. The sorting was done on the basis of norms by Yoon et al.

(2004) and Van Overschelde et al. (2004). All words used as distracters were recorded anew in a female voice for the present experiment.

Results and discussion

The descriptive statistics for correct recall can be found in Table 1.

Prime trials: As in Experiment 5, we collapsed across ND-match and ND-mismatch conditions which did not differ from each other at this point of the procedure. The resulting one-way ANOVA comparing performance under related distraction, unrelated distraction and no distraction was significant, $F(2, 58) = 36.62$, $MSE = .002$, $p < .001$, $\eta_p^2 = .56$. Planned comparisons showed that performance was not significantly worse under unrelated distraction than when no distraction was presented, $t(29) = 1.91$, $SE = .01$, $p = .066$, $d = 0.36$. Performance was, however, significantly worse under related distraction than under unrelated distraction, $t(29) = 5.86$, $SE = .01$, $p < .001$, $d = 0.98$.

Probe trials: Performance was markedly lower on probe than on prime trials. For example, a comparison of prime and probe trials within the ND-mismatch condition, for which prime and probe trials differed exclusively in terms of frequency of TBR words, revealed a significant difference of 11%, $t(29) = 7.47$, $SE = .01$, $p < .001$, $d = 1.55$. This difference is similar to a difference in prime and probe performance observed in the study by Marsh et al. (2012, Figure 3, p.1382), and the results confirm that the manipulation of taxonomic frequency was effective.

Performance on probe trials was analyzed with a 2 (distraction on prime: present vs. absent) x 2 (semantic relationship between prime probe: match vs. mismatch) ANOVA. For trials with semantic match, the preceding distraction was related (the RD-match condition), whereas for trials with semantic mismatch, the preceding distraction was unrelated (the UD-mismatch condition). The ANOVA yielded the main effect of semantic relationship, $F(1, 29) = 21.09$, $MSE = .003$, $p < .001$, $\eta_p^2 = .42$, but no effect of distraction on prime, $F < 1$, and no interaction, $F(1, 29) = 2.38$, $MSE = .002$, $p = .134$, $\eta_p^2 = .08$. These results once more indicate that proactive interference operates in this design and its magnitude is unrelated to the presence of distraction at prime.

The specific comparisons conducted in addition to the omnibus ANOVA showed that performance was lower in the RD-match vs. UD-mismatch condition, $t(29) = 4.57$, $SE = .01$, $p < .001$, $d = 0.86$. This result indicates that negative priming in free recall was obtained even with low taxonomic frequency distracters, failing to replicate positive priming effects reported by Marsh et al. (2012, Experiment 2). The Bayes factor for the contrast between the positive priming hypothesis derived from the results of Marsh et al. (2012) and the null hypothesis showed strong evidence for the null hypothesis, B = 0.046. Further, a comparison of the ND-match vs. ND-mismatch conditions again showed lower performance in the former, $t(29) = 2.49$, $SE = .01$, $p = .019$, $d = 0.43$, demonstrating the negative effect of semantically-driven proactive interference. Finally, a direct comparison of the condition utilizing previously ignored related distracters (RD-match) to the condition preserving semantic match but using novel TBR words at probe (ND-match) showed no significant difference, $t(29) = 1.29$, $SE = .01$, $p = .207$, $d = 0.28$, with a numerical difference favouring performance in the ND-match condition. The Bayes factor for the contrast between the positive priming hypothesis derived from the results of Marsh et al. (2015) and the null hypothesis showed strong evidence for the null hypothesis, B = 0.093. This null result is consistent with the results obtained in Experiments 4 and 5, as well as the combined analysis of Experiments 2 and 3, inasmuch as it indicates once more that the presence or absence of related distraction at prime has no reliable effect on performance at probe.

To summarize, the present experiment supports the general conclusion that the phenomena attributed to negative priming in free recall by Marsh et al. (2012) are better accounted for by proactive semantic interference. The results are inconsistent with the results of Marsh et al. (2015) since they show no positive priming when semantic match is preserved in both compared conditions. Contrary to previous reports, the taxonomic frequency manipulation – although clearly effective in depressing performance on probe trials – did not abolish semantically-driven proactive interference or the pattern of negative priming in free recall. The results also do not support the contention that low taxonomic frequency distracters are primed, facilitating performance for these items at probe. Once again, whether auditory distracters were present or absent at prime had no discernible effect on performance on subsequent probe trials.

General Discussion

In six experiments the mechanisms of the effect of negative priming in free recall were tested. To date, there are two published studies concerning this effect: Marsh et al. (2012) and Marsh et al. (2015). These studies used markedly different paradigms and thus our findings in relation to these two studies will be discussed separately. Overall, however, we claim that – on reconsideration – there is no substantial evidence that an inhibitory mechanism is responsible for negative priming in free recall. We argue that the results of the original study of Marsh et al. (2012) should be assigned to semantically-driven proactive interference operating within the original design. As for the revised paradigm of Marsh et al. (2015), we cannot offer any resolution on *theoretical* grounds, as the results presented in that study were not replicated. We are, however, able to amalgamate the *statistical* evidence across studies meta-analytically which gives an overall assessment strength of the combined evidence. These issues are addressed in turn.

The current study was conducted with an explicit aim of further investigating the negative priming in free recall effect as reported in the original paper of Marsh et al. (2012). A problem with the original application of the theoretical framework of inhibition to the negative priming phenomenon was identified, revolving around the fact that the paradigm designed by Marsh et al. (2012) required participants to restudy presumably inhibited items with the presumption that this would result in poorer subsequent recall. Previous investigations concerning inhibition however (e.g., Storm et al., 2008) have explicitly suggested that re-presentation of previously inhibited items should lead to better, rather than worse, performance compared to a baseline of non-inhibited items. In short, the original design might, according to prominent formulations of the inhibitory mechanism (Bjork & Bjork, 1992), lead to positive rather than negative priming. In light of this reasoning, we reconsidered the evidence for inhibition and queried whether one of two alternative mechanisms that, arguably, had received insufficient consideration previously, could be responsible for negative priming in free recall: response withholding due to source confusions and semantically-driven proactive interference. This process has led to a number of conclusions.

First, in Experiment 2 no support was found for the response withholding account. Equating the number of contexts in which TBR items of the ignored repetition and control conditions occurred did not eliminate the effect (an observation confirmed in later experiments), consistent with the inhibitory account. However, subsequent experiments in this series provided support for the semantically-driven proactive interference hypothesis rather than the inhibitory hypothesis as the mechanism of the negative priming effect.

Second, Experiment 3 (and, subsequently, Experiments 5 and 6) showed that proactive interference influences the finding when a design is used which contrasts ignored repetition trials preceded by prime trials utilizing TBR items from the same semantic category with control trials preceded by prime trials utilizing TBR items from a different semantic category. Even in the design with no auditory distracters performance in such a comparison was lower on the ‘ignored repetition’ probe trials. This effect is perhaps not surprising given the long tradition of research on semantically-driven proactive interference (e.g., Wickens, 1970). However, recent studies have shown that some forms of proactive interference can be eliminated by testing memory for the potentially interfering lists (Bäuml & Kliegl, 2013; Szpunar, McDermott, & Roediger, 2008) and the negative priming design involves free recall tests administered after each prime trial so it was by no means obvious that these tests would not serve to protect the following probe trials from proactive interference. A condition without such prime trials tests was not employed, so the extent of such protection (if any) cannot be determined but it is certainly not absolute because negative effects of semantically-driven proactive interference are observed despite tests on prime trials (Experiments 3 and 5).

Third, Experiments 4 and 5 (as well as the combined analysis of Experiments 2 and 3) demonstrate that proactive interference is sufficient to explain the pattern of negative priming in free recall observed by Marsh et al. (2012). In Experiment 4, negative priming in free recall was no longer observed when proactive interference was controlled for by creating a semantic match between prime and probe trials in the control condition. Combining the results of Experiments 2 and 3 preserved semantic match across both ignored repetition and control (no distracter) conditions, and comparison of these data revealed that these conditions were indistinguishable from each other in terms of performance on probe trials. Experiment 5 again documents the same result with a design in which no unrelated distraction was played at prime trials in the control condition. Thus, the presence or absence of related distraction at prime did not impact upon performance on probe trials in any reliable way.

Fourth, Experiment 6 concerned the issue of taxonomic frequency as related to negative priming in free recall. Marsh et al. (2012, Experiment 2) argued that when low taxonomic frequency items serve as distracters at prime, positive rather negative priming of these distracters is observed at probe, based on the idea that such items do not compete for attention strongly enough to trigger the inhibitory mechanism. These results are surprising given the confound of semantic match between ignored repetition and control conditions in the original procedure because the absence of negative priming in free recall necessarily implies the absence of semantically-driven proactive interference (and positive priming even implies proactive facilitation). We are unaware of any previous studies showing that low taxonomic frequency items do not suffer semantically-driven proactive interference and thus Experiment 6 tried to replicate the reversed effect. However, this experiment instead resulted in a reliable effect of proactive interference with low taxonomic frequency items serving as TBR items at probe. Furthermore, just as in previous experiments in this series, an equivalent level of memory impairment was observed whether or not low taxonomic frequency items served also as related distracters in the ignored repetition condition. These results thus fail to replicate the absence of negative priming in free recall with low taxonomic frequency distracters and do not support the inhibitory account of this effect. They are, however, entirely consistent with a proactive interference account.

Overall, the present study provides evidence for the role of proactive interference in the design used by Marsh et al. (2012). Proactive interference is necessary to describe our results and it also seems sufficient to account for all replicable results obtained in the original paradigm developed by Marsh et al. (2012). By contrast, our results fail to support the inhibitory account proposed by Marsh et al. However, the present results should not be extended to argue against an inhibitory framework of forgetting in general. The purpose of the study was to assess the argument for inhibition as responsible for particular patterns documented by Marsh et al. The fact that evidence is reported which questions the inhibitory account in this particular instance has no bearing on the status of inhibition as an explanatory mechanism in other paradigms.

Turning now to the study by Marsh et al. (2015) the situation becomes more problematic because some of the statistically significant findings from this earlier study are directly at odds with the data obtained here. It is worth stressing that the experiments by Marsh et al. (2015) were aimed at issues of individual differences in the effects of semantic distraction (including negative priming) rather than directly to investigate the basis of negative priming effect. Nevertheless, the obvious tension between the contrasting sets of results should be resolved if possible. The paradigm used in Marsh et al. (2015) imposes semantic match between prime and probe trials in the control condition, thus equating ignored repetition and control conditions in terms of proactive interference in exactly the same manner as the current Experiment 4, which found no evidence for negative priming in free recall. We show the same pattern again in Experiment 5 with a very similar design, differing only in the fact that unrelated distracters were not included in prime trials of the control condition.[4] These results stand in direct contrast to the results of Experiments 2 and 3 reported in Marsh et al. (Experiment 2 using auditory distracters of mixed taxonomic frequency and Experiment 3 using auditory distracters of high taxonomic frequency), which both showed negative priming under conditions of equated proactive interference. Furthermore, Experiment 4 of Marsh et al. used low taxonomic frequency distracters and positive priming was reported under conditions of equated proactive interference. The current Experiment 6 utilised conditions almost identical to the ones employed by Marsh et al.

[4] Note that negative priming in free recall is a comparison of recall performance for items that previously served as related distracters to novel items and thus there is nothing in the concept that would require unrelated distraction at prime.

(again, except for the absence of unrelated distraction at prime in the control condition) and failed to replicate the pattern of positive priming.

The reasons for these discrepancies are unclear and no clear theoretical or methodological reasons for this have yet been proposed (formally or informally) by any of the researchers concerned. The statistically most likely explanation would be a Type 2 error in each of the current data-sets, were it not for the conceptual problems identified here and the accumulation of evidence across studies. Therefore, to statistically assess all of the available evidence we carried out a Bayesian analysis on the evidence for and against the concept of inhibition as the basis of negative priming effects. Here, we use the procedure outlined by Parmentier and Beaman (2015) to identify a prior level of confidence in the inhibition account and update our confidence in this account meta-analytically in manner consistent with Bayes' theorem, using each separate experiment as an independent source of evidence. Our initial confidence in the inhibitory account was calculated using the mean and standard error of Marsh et al.'s (2015) Experiment 2 results to represent the mean and standard deviation of the distributions of the prior and updating these using the mean and standard error of the current Experiment 4 as the corresponding likelihood values in order to obtain the posterior mean and standard error (see Dienes, 2008, 2011). Once all data have been entered in this way, the final posterior means and standard errors for the data thus obtained were entered into Dienes' (2011) Bayes factor calculator to enable us to assess the relative evidence for theoretical (inhibitory) and null hypotheses.

To calculate the final Bayes factors we assume that the inhibitory account predicts a uniform distribution of potential priming with the lower bound being zero difference between control and negative priming conditions and the upper bound being equivalent to the previously observed difference (from Experiment 1) between control and negative priming conditions when proactive interference was not controlled for. This seems reasonable because it assumes, along with Marsh et al. (2012, 2015), that inhibition cannot improve later recall but can only result in poorer subsequent recall (a lower bound of zero) and that the "pure" effects of inhibition cannot be any greater than the effects of inhibition when proactive interference is also a potential confound (upper bound). We have no reason to suppose that any outcome between these two boundaries is any more likely than any other outcome within this region and therefore must assume a uniform distribution. Using this procedure, an overall Bayes factor of .15 is obtained for all the available data where no proactive interference is expected (Marsh et al., 2015, Experiment 2, Experiments 4 and 5 of the current data-set), that is substantial evidence in favour of the null. We conclude therefore that the balance of evidence supports the proactive interference hypothesis (which predicts such a null result) over the inhibition hypothesis of the negative priming effect.

The Bayesian analysis indicates that our results provide substantial evidence that negative priming in free recall does not emerge when proactive interference is controlled. In our view, the one remaining way to remove the discrepancies between our results and the results obtained by Marsh et al. (2015) is to evoke the issue of individual differences. As mentioned earlier, the study by Marsh et al. was mostly devoted to examining the role of individual differences in controlling auditory distraction. Previous work in the area of memory inhibition showed that the effectiveness of the inhibitory mechanisms is related to the working memory capacity (e.g., Aslan & Bäuml, 2011). Marsh et al. showed that negative priming in free recall they were able to obtain with their modified paradigm was indeed positively correlated with the measure of working memory capacity (see also Beaman, 2004). Measures of working memory capacity were not collected in the present study and thus one reason for the failure to obtain reliable effects of negative priming in free recall might stem from the particular sample used in our experiment which, according to this explanation, would consist of participants with relatively limited effectiveness of executive functions.

Although there is no a priori reason to suppose this to be the case (the populations sampled appear comparable in other respects) we cannot rule out this hypothesis and thus we suggest that serious consideration be given to individual differences in any further investigation into negative priming in free recall. Such evidence also requires careful methodological consideration to avoid replicability problems (e.g.. Pan, Pashler, Potter, & Rickard, 2015).

To conclude, the present series of experiments have tested the inhibitory hypothesis for negative priming in free recall against two alternatives: source confusion and proactive interference. On the basis of Experiment 2, source confusion can be ruled out as a potential explanation of this effect. When an ignored repetition condition is tested against a control condition in which equivalent source confusion for the TBR items is possible, the negative effects of ignoring semantically-related distracters remain (note that the conditions, and results, of Experiment 2 are also replicated in the larger designs of Experiments 5 and 6). Experiment 3 demonstrated that PI from previous lists occurs in the absence of related auditory distracters and Experiments 4-6 then compared the effects of ignoring related distracters against a control condition which included PI. The results have forced us to reconsider the role of inhibition in negative priming because the negative priming effect did not replicate under such conditions, suggesting that the original finding might – wholly or in part – be a consequence of PI rather than inhibition. A Bayesian meta-analysis combining these results with previous data more supportive of inhibition (Marsh et al., 2015) reinforces this conclusion. The theoretical problem which provided the impetus for the current studies – how inhibited items are re-learned – remains. In particular, whether inhibited items should be presumed to be harder to re-learn (by analogy with the negative priming in selective attention literature) or whether re-presentation of previously inhibited items should facilitate learning (cf. Storm et al., 2008). On reconsideration therefore, any theoretical framework of inhibitory control within memory should address this issue to produce a coherent account within the broader theoretical approach to memory in which the role of inhibitory processes is of critical importance. Empirically, any endeavour in this direction using negative priming in free recall procedures should concentrate on tests which are specifically designed to avoid the conflation of differences in proactive interference between experimental and control conditions with the conditions presumed essential to produce negative priming.

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Table 1. Mean proportions of recalled items averaged across all lists in a given condition, presented as a function of type of trial (prime vs. probe) and experimental condition: semantically related and unrelated auditory distraction for prime trials and ignore repetition and control for probe trials. In Experiment 3 no auditory distracters were played and the names of conditions are kept for consistency to Experiments 1-2. The same pertains to 'no distraction' rows in Experiments 5 and 6. Standard errors of the means are given in parentheses.

	Prime trials		Probe trials	
	Semantically related	Semantically unrelated	Ignored repetition	Control
Experiment 1	.39 (.011)	.43 (.015)	.41 (.009)	.44 (.014)
Experiment 2	.39 (.016)	.42 (.017)	.43 (.013)	.46 (.015)
Experiment 3	.45 (.017)	.46 (.015)	.40 (.015)	.47 (.017)
Experiment 4	.36 (.014)	.39 (.016)	.40 (.014)	.38 (.017)
Experiment 5				
distraction	.37 (.011)	.40 (.013)	.41 (.009)	.47 (.011)
no distraction	.44 (.011)	.43 (.009)	.39 (.009)	.46 (.013)
Experiment 6				
distraction	.42 (.014)	.49 (.015)	.36 (.007)	.42 (.017)
no distraction	.51 (.014)	.52 (.015)	.38 (.013)	.41 (.013)

FIGURE CAPTIONS

Figure 1: Experiments 1, 2, and 4. These examples shows how the modified and matched control condition lists provide a better control for the ignored repetition condition than achieved in Marsh et al. (2012) and in Experiment 1. This enables the source monitoring hypothesis and proactive interference hypothesis of negative priming to be tested.

FIGURE 1

Trial:	Ignored Repetition Condition	Previous Control (Exp 1)	Modified Control (Exp 2)	Matched Control (Exp 4)
N (prime):				
SEE AND RECALL:	Ruby, Emerald, Topaz etc	Ruby, Emerald, Topaz etc	Ruby, Emerald, Topaz etc	Ruby, Emerald, Topaz etc
HEAR AND IGNORE:	Diamond, Garnet, Pearl etc	Desk, Table, Cupboard etc	Desk, Table, Cupboard etc	Desk, Table, Cupboard etc
N+1 (probe):				
SEE AND RECALL:	Diamond, Garnet, Pearl etc	Chair, Bed, Wardrobe etc	Desk, Table, Cupboard etc	Diamond, Gamet, Pearl etc